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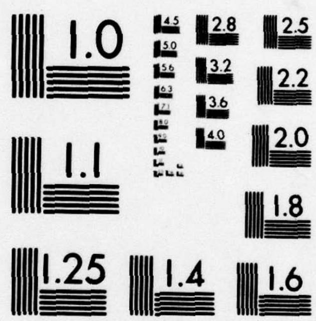

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6 SUBPOTABLE WATER REUSE AT ARMY FIXED INSTALLATIONS: A SYSTEMS APPROACH.

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by

10 Curtis J. Schmidt
Ernest V. Clements
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12 170

11 August 1979

Environmental Protection Research Division
U.S. Army Medical Bioengineering
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This report concerns the treatment and reuse of wastewater at fixed Army installations. The objective was to provide a tool that could be used by the Army in assessing the potential for water reuse at all their fixed facilities; in isolating those bases with the best reuse potential; and in evaluation conceptual reuse schemes at those bases.

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All major Army activities involving water and wastewater were researched and described. In addition, a three-tiered water reuse model was developed that leads the evaluates through three phases of evaluation culminating in the use of a sophisticated computer model.

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EXECUTIVE SUMMARY

This report concerns the treatment and reuse of wastewater at fixed Army installations. The objective was to provide a tool that could be used by the Army in assessing the potential for water reuse at all their fixed facilities; in isolating those posts with the best reuse potential; and in evaluating conceptual reuse schemes at those posts.

To achieve this objective, two paths were pursued. First, major Army activities involving water and wastewater were identified and described as to: water use and wastewater characteristics, tolerable water quality if reclaimed water were to be used, potential as a donor or recipient of reclaimed water, and the potential for internal reuse at the activity. These data are essential and form a basis for constructing feasible reuse networks.

Secondly, a water reuse evaluation model was developed. This model involves three phases or tiers. Tier I is a comprehensive questionnaire that allows a concise overall evaluation of the reuse potential of a post in a short amount of time. Posts that score well on Tier I may then be evaluated under Tier II. This tier leads the evaluator through a deeper analysis of reuse possibilities on the post, and ends with a brief economic analysis of the fundamental reuse schemes selected for the post. Should this analysis show reuse to be economically beneficial, Tier III is applied. Tier III is a detailed survey that should be used only at posts with proven reuse potential. Field data from activity records and sampling, as well as conceptual reuse networks, are used as input to a mathematical model that determines piping, pumping, storage, and treatment requirements, and costs for the entire reuse system. At this point, the Army post should be ready for full-scale engineering design of the most effective reuse system.

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Without the cooperation and guidance of these people, it would have been impossible to develop accurate activity descriptions and a sound reuse evaluation model.

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I

BACKGROUND, OBJECTIVES, AND APPROACH

BACKGROUND

The U.S. Army's primary mission is to secure our national defense. In carrying out this mission, they are also charged with maintaining the quality of the environment, and compliance with federal and state environmental regulations in this regard. As a part of their environmental program, the Army is encouraging the conservation of water supplies and the reuse of valuable resources at their fixed installations. One means of achieving this is through wastewater treatment and reuse.

Wastewater reuse can have several benefits for Army posts: fresh water supplies can be conserved by substituting reclaimed water for subpotable uses; problems with pollution control can be alleviated by internal recycling and reuse at specific activities; treatment performance can be enhanced by reusing water and reducing the hydraulic load on the treatment plant; nutrients in the wastewater can be utilized as fertilizer in irrigation waters; zero discharge reuse schemes can eliminate the problems of meeting stringent discharge regulations; and, by reducing wastewater through reuse, posts can save money on water purchase and sewer discharge fees.

Another benefit of reuse is that it highlights the needs for source reduction of waste, and for proper handling and disposal of industrial residues and wastewaters. Elimination of strong wastes from the general waste stream enhances reuse potential and eases pollution abatement problems. Refer to the Army Sanitary and Industrial Waste Manual (1) for proper housecleaning, handling, and disposal procedures for Army industrial wastes.

To date, reuse at fixed Army installations has been considered only when a specific problem has forced authorities to evaluate reuse as one potential solution. The recent passage of the Clean Water Act (PL95-576) will increase this type of review, since it <u>requires</u> consideration of wastewater reuse as one option whenever new water and/or wastewater treatment facilities are planned for construction.

However, the Army still has no overall method of assessing the potential for reuse throughout its fixed installations. This report provides such a tool. The evaluation model developed herein, provides a systems approach for assessing the potential of water reuse at all Army fixed facilities. The model is directly applicable to those posts where new water and wastewater construction is planned and, thus, where an evaluation of reuse is mandated by law.

This report is limited to subpotable reuse, and is concerned only with permanent, fixed Army posts. Army ammunition plants are excluded. Subpotable reuse includes not only end-of-pipe reuse, such as reusing STP and IWTP effluents, but also internal waste segregation, treatment and reuse at specific activities, such as reusing treated wash rack water or plating shop rinse waters.

OBJECTIVES

The objective of this project was to develop a tool that can be used by the Army in assessing the potential for water reuse at their fixed installations; in isolating posts with the best potential; and in evaluating conceptual reuse systems at those posts.

In meeting this objective, Army activities were to be researched and discussed as to water and wastewater characteristics, flows, and reuse potential. In addition, a reuse evaluation model was to be developed that incorporated a three-tiered approach as discussed in the next section.

APPROACH

The following approach was used in achieving the project objective:

- Conduct literature search: a search of Army data, other military information, and civilian literature was carried out to obtain data on individual Army activities.

- Conduct case study investigations: to obtain more first-hand activity data and to test the Tier I model, three Army posts were visited by project personnel. The posts were: Ft. Ord, California; Ft. Jackson, South Carolina; and Anniston Army Depot, Alabama.

- Develop reuse evaluation model: a three-tiered evaluation model was developed to aid the Army in evaluating reuse potential at fixed installations. Since there are over 130 Army posts in the United States, the first tier had to be a simple, straightforward model that could be used to assess a post's overall reuse potential with about 1 man-day of effort. Tier II will be applied at posts that score well on Tier I. Tier II provides a type of cook-book approach, leading the evaluator to an eventual comparison of total costs for various reuse schemes with nonreuse options at each post. Tier III is a detailed decision-making model that incorporates a sophisticated computer program to aid Army engineers in selecting and costing conceptual reuse systems at posts with the best reuse potential.

- Modify reuse computer program: a previously developed U.S. Air Force computer model, that is now part of the Tier III evaluation, was modified to reflect Army activities, treatment methods, and operating practices.

II

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

- Initial surveys conducted during the study substantiate that several Army posts across the country could benefit by construction of either complete reuse systems or treatment/recycle units at individual activities.

- The following are positive factors for reuse at fixed Army facilities:

  - Water supply shortages, problems, or high cost

  - Direct discharge of treated or untreated effluent to surface water or land (NPDES permits required)

  - Wastewater treatment/discharge problems or high cost

  - Presence of high-water-use activities that could use reclaimed water:

    - Golf course irrigation
    - Landscape irrigation
    - Cooling towers
    - Plating shop
    - Industrial laundry
    - Wash and steam cleaning racks
    - Artificially filled recreational lakes
    - Dynamometers
    - Air pollution scrubbers
    - Engine test cells

  - Arid climate

  - Positive attitudes toward reuse by key base personnel

  - Absence of legal/institutional constraints to reuse.

- The following are negative factors for reuse at fixed Army facilities:

  - Ample, reliable water supplies

  - Long-term water purchase or wastewater discharge (to municipal or regional sewer system) agreements that constrain water or wastewater reductions

- Absence of irrigation potential
- Lack of enthusiasm for reuse among key personnel.

- At this point, it appears that the following types of bases have the greatest potential for reuse:

  - Depots with many large industrial activities. These posts use large amounts of water, often have several direct discharges, and may have significant pollution control problems.

  - TRADOC and FORSCOM posts located in water-short areas with large irrigation demands. These troop-oriented posts rarely have many large industrial activities. However, this means that the post wastewater is primarily domestic with few problem contaminants and; therefore, is excellent for reuse for irrigation and cooling after secondary treatment and filtration.

  Note that these are very broad categories, and that there will undoubtedly be many individual posts outside of the categories with specific factors that make reuse attractive.

- Secondary treatment is provided by trickling filters at most posts. These facilities will have to be upgraded by filtration to provide effluent quality commensurate with that required for most reuse activities.

- Some Army activities have good potential for internal treatment and reuse. These include:

  - Cooling towers
  - Dynamometers
  - Plating and metal finishing
  - Air pollution scrubbers
  - Wash racks
  - Steam cleaning racks
  - Industrial laundries
  - Test cells.

- Opportunities for "and-of-pipe" reuse include at the use of effluent from sewage treatment plants (STPs) and industrial waste treatment plants (IWTPs) for irrigation and makeup to cooling systems.

- Most bases have not taken full advantage of the benefits of wastewater reuse.

RECOMMENDATIONS

- More research is needed to determine the required water qualities and quantities for certain activities that could use reclaimed water. Activities for which more data is needed are:

  - Steam cleaning racks
  - Rotary and fixed-wing aircraft wash racks
  - Industrial laundries.

  Of particular importance is the required bacterial and viral quality if STP effluent were to be used at the wash racks.

- A renewed emphasis on source reduction should be undertaken to enhance pollution control efforts and to improve effluent quality for reuse applications. This may be especially important at installations where many heavy industrial activities are performed and dozens of hazardous wastes are generated. Key activities where source reduction and house cleaning are most important are:

  - Paint stripping and painting
  - Nondestructive testing
  - Metal plating and finishing
  - Degreasing/metal cleaning
  - Pesticide disposal
  - Chemical laboratories
  - Vehicle/aircraft maintenance
  - Fuel spill control.

- The evaluation model should be applied immediately at those bases planning construction of water or wastewater facilities to assist in complying with the requirements of the Clean Water Act (PL 92-500 and PL 95-217).

- The evaluation model should be excercised by a limited group of knowledgeable individuals so that the results will be consistent. This is especially true of Tiers II and III.

- Concurrent with the application of Tier I to all Army bases, several Tier II evaluations should be conducted during the summer of 1979 to make minor modifications to the approach. Tier III has been tested and modified during this project and under previous Air Force contracts.

III

ARMY ACTIVITY DESCRIPTIONS

This section of the report briefly discusses the types of Army posts, their unique characteristics, and their similarities with civilian counterparts. A concise summary of each important Army activity, with regard to water and wastewater characteristics and reuse potential, is then provided.

TYPES OF ARMY POSTS

There are approximately 135 fixed Army installations in the United States. These are divided into two categories: 1) troop-oriented; and 2) maintenance/storage-oriented facilities. The troop-oriented facilities include both TRADOC (Training and Doctrine Command) and FORSCOM (Forces Command) installations. The maintenance/storage-oriented facilities are called depots. Table 1 summarizes the prevalence of various water-related activities at Army posts and depots. As shown, most posts have many activities that use and generate water and wastewater, including domestic, industrial, recreational, and pollution control types. Note that Table 1 does not indicate the size of the operation or the waste volumes used, which are important considerations for reuse. Key Army activities for reuse consideration are:

- o Sewage and industrial wastewater treatment plants
- o Irrigated golf courses and landscape
- o Large cooling towers (including those associated with engine and transmission test cells)
- o Plating shops
- o Large wash racks and steam cleaning facilities
- o Other large industrial water users.

Most posts appear to have several of these activities.

Basically, TRADOC and FORSCOM installations have similar water- and wastewater-related activities. They are similar in many ways to small towns, with a few scattered industrial, business, recreational and commercial establishments. Typically, they provide several types of post housing, and have a hospital; post office; industrial laundry; laundromats; cafeterias; restaurants; mess halls; various community facilities (school, church, gymnasium, swimming pool, auditorium, hobby shops, golf course, etc.); protective facilities (police, fire, jail); commercial facilities (commissary, post exchange, gas station); office buildings, photographic lab; and wastewater treatment plant. They also commonly have their own heating and cooling and, possibly,

TABLE 1. PREVALENCE OF WATER-RELATED ACTIVITIES AT ARMY POSTS

Activities	Posts														
	Ft. Bliss	Corpus Christi A.D.	Ft. Carson	Ft. Campbell	Ft. Huachuca	Ft. Hood	Ft. Knox	Letter Kenny A.D.	Lex. Blue Grass A.D.	New Cumberland A.D.	Ft. Rucker	Sacramento A.D.	Ft. Sill	Tobyhanna A.D.	Tooele A.D.
1. Aircraft Wash Rack		X	X	X	X	X				X	X		X		
2. Ash Handling				X			X		X					X	
3. Base Housing	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4. Boilers	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5. Cafeteria, Mess Halls, Restaurants	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6. Cooling Tower	X	X		X	X	X	X	X	X	X	X	X	X	X	X
7. Dynamometer	X	X	X	X		X		X			X		X		X
8. Equip./Vehicle Maint. Shops	X	X	X	X	X	X	X	X		X	X	X	X	X	X
9. Fire Protection/Spill Washdown Reservoir	X		X	X	X	X	X		X	X	X			X	X
10. Golf Course	X	X	X	X	X	X	X	X	X	X	X	X	X		
11. Hospital			X	X	X	X	X				X		X		
12. Industrial Laundry		X	X	X	X		X			X	X		X		X
13. Ind. Waste Trt. Plant		X	X	X			X	X				X			
14. Irrigation	X	X	X				X	X		X	X	X	X		X
15. Laundromats	X		X	X	X	X	X				X				X
16. Metal Finishing/ Plating		X	X	X			X	X		X		X		X	
17. Metal Cleaning		X	X	X		X	X	X	X	X	X	X		X	X
18. Motor Pool	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
19. Nondestructive testing		X	X			X	X	X	X	X	X	X	X	X	X
20. Paint Booths	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
21. Photography Labs.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
22. Recreational Lake			X	X	X	X	X	X	X	X	X		X	X	
23. Sewage Trt. Plant	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
24. Steam Cleaning		X	X	X	X	X		X		X	X	X	X	X	X
25. Swimming Pool	X	X	X	X	X	X	X	X	X	X	X	X	X		X
26. Vehicle Wash Rack	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
27. Water Treatment Plant		X		X	X		X	X	X		X				
28. Wet Scrubbers (Air Pollution)		X												X	

electricity-generating plants. Industrial-type activity is usually limited to vehicle and aircraft maintenance and washing. Thus, wash racks, vapor degreasers, steam cleaners, and paint booths are common.

U.S. Army Depots are maintenance-oriented, and perform such activities as repairing and maintaining tanks, weapons, heavy equipment, electronics, helicopters, and engines. A few select depots work only with munitions. These are excluded from this study, as are specialty bases and storage depots. The depot carries out either repair, maintenance, or complete overhaul and rebuilding of the assigned equipment. The character of depots varies depending on the mission, but most are industrial in character. Metal cleaning, electroplating and metal finishing, wash racks, steam cleaning, and paint booths are common activities. Depots often operate independent industrial waste treatment facilities, as well as sewage treatment facilities.

Many of the activities at Army posts are similar to civilian operations, such as laundromats, car washes, recreational activities, office buildings, maintenance shops, sewage treatment plants, etc. However, there are several important factors that make Army installations unique. These are as follows:

- Post populations can fluctuate greatly between day and night, since a large number of civilians may come into a post to work during the day.
- Post populations often decline significantly on weekends.
- Post populations vary depending on staffing levels, training programs, maneuvers, etc.
- Army personnel are a captive audience in that they must follow all commands and rules, including any that may pertain to water reuse. Thus, water conservation/reuse strategies can be more easily and quickly implemented, and more directly enforced.
- Army design/construction projects usually operate under short, rigid time frames necessitating strict adherence to schedules. Thus, the luxury of long drawn-out planning and designs may not be available.
- The Army is limited in treatment plant operator training. As a result, operators are usually not very experienced, and are likely to have little background in sanitary engineering. This is one reason why the Army has often selected trickling filter plants, rather than more sophisticated and higher performance activated sludge plants. Trickling filters are much simpler to operate. Also, most of the Army's trickling filter plants were built in the 1950's when that technology was standard

design. Designs for reuse systems that include treatment must reflect the limited level of operator experience available.

INDIVIDUAL ACTIVITY DESCRIPTIONS

The remainder of this section provides summaries of water reuse-related Army post activities. The following topics are covered for each activity:

1. Description: A general description of each activity is provided, indicating the purpose of the activity and its basic operating procedures.

2. Flow: Water usage and wastewater generation are discussed, including daily average flows, flows per unit processed, and seasonal patterns.

3. Tolerable Water Supply Quality: Tolerable water supply quality is estimated for each activity. For some activities, such as irrigation and boiler and cooling tower makeup, these limits are fairly well documented. For most activities, the limits had to be estimated since published data was not available.

4. Typical Effluent Quality: Activity wastewater characteristics are summarized.

5. Reuse Potential: Each activity is discussed as to its potential as a donor or recipient of reclaimed water. This includes the potential for cascading, or receiving effluent directly to or from other activities, as well as using treatment plant effluent.

6. Internal Recycling: This final section discusses the potential for treatment and reuse within the activity itself. Internal recycling may involve relatively simple procedures, or may include sophisticated pretreatment where feasible. Reuse may occur in an auxilliary process, such as the use of boiler blowdown for stack gas scrubber makeup.

Tables 2 and 3 summarize activity effluent quality and tolerable water quality for the major sources of wastewater and potential users of reclaimed water, respectively. Note that data for metal electroplating and finishing were not included in Table 2, although this activity may be an important source of reclaimed water for a particular post. The quality of metal plating and finishing wastewater varies depending on the plating process and rinses used. Thus, no "typical" values for wastewater could be assigned.

TABLE 2. SOURCES OF RECLAIMED WATER - TYPICAL EFFLUENT QUALITY

Constituent	Concentration (mg/L) Base Housing*	Hospitals/ Clinics	Industrial Laundries	Laundromats	Boilers	Cooling Waters#	Air Pollution Wet Scrubbers	Vehicle Wash Racks	Aircraft Wash Racks	Steam Cleaning	Metal Cleaning**	Paint Booths	Photographic Laboratories
BOD_5	200	250	450	200	5.0	7.0	10	60	5,700	1,300		8,100	300
COD	300	850	2,000	400	15	35	720	900	8,400	2,800	3,000	13,600	500
pH (pH units)		7.6	11.2	8.2	10.0	7.4	4.0			9.7	9.0		7.8
TDS	300+SWC†	1,400	2,000	360	3,500	5xSWC	5,000						2,900
O&G	50-100	45	300	750	0.5		0.3	60	280	245	350	280	4.0
SS	300	200	1,000	130	50	30	3,270	2,000	470	1,000	300	2,800	225
PHNL	0.15				0.5	0-0.1	0 001	0.01	8.5	8.0	70	1.2	0.001
Ag		0.3											0.5
B	1.0+SWC				10		0.1	0.01	0.1			0.1	18
Ca		15	740					31					
$CaCo_3$	80+SWC			250	50		200						
Cd		0.02	0.04							0.5	0.5		
Cr		1.1	0.06		0.005	0.05	0.01			0.3	25	13	
Cu			0.3		3.0	0-2	0.005			0.2		0.005	
CN	0.01				2.5			0.005	0.005	<0.01	0.6		4.8
Cl-	100+SWC				1,000	5xSWC	400						
Fe	1.0+SWC	0.3	1.0		2.5	0.6	5.3	4.7	1.1			3.2	2.0
K		34											
Mn					2.5								
Mg		16	6.4					15					
Na	50+SWC	360			1,000		72						
Ni			2.1		0-0.1					<0.05			
NH_4	30				2.0		0.1	0.01	0.1			0.1	16
NO_3				1	150		28	3.3	0.8			28	8.8
P (Total)						2.1		33					
Pb		0.3	0.7					2.5		0.6	0.4		

TABLE 2 (continued)

Constituent (mg/ℓ)	Base Housing*	Hospitals/ Clinics (gal/bed)	Industrial Laundries (gal/lb laundry)	Laundromats (gal/wash)	Boilers	Cooling Waters#	Air Pollution Wet Scrubbers	Vehicle Wash Racks	Aircraft Wash Racks	Steam Cleaning	Metal Cleaning**	Paint Booths	Photographic Laboratories
PO_4	10	170		220	60		5.4	12	80	65	40	3.0	9.3
Si			130		2.5								
SO_4		35				5xSWC							
Zn			0.5		0-1			2.9		2.0	6.0		
Hardness (as $CaCO_3$)					50	5xSWC							
Detergents (as MBAS or ABS)		75		60							3.0	4,900	
Hexane Sol.				32									
ALK (as $CaCO_3$)	50-150	125	500	182	500	5xSWC		115			400		
Level of Confidence††	1	1	1	1	1	1	3	1	2	1	1	2	1

*Applies to officers' quarters, BOQ, VOQ, barracks, and unclassified office space, as well as family housing.
†SWC = Source water concentration
#Recirculating type
**Rinse waters
††"Level of Confidence" denotes confidence in data shown: 1 = High level of confidence. Well documented.
2 = Moderate level of confidence. Some documentation, some values may be engineering estimates.
3 = Low level of confidence. Limited documentation, most values are engineering estimates.

NOTE: Metal electroplating and finishing is a potential source of reclaimed water. The effluent contains high concentrations of various metal ions and cyanides, depending on the processes used, and small amounts of BOD, P, O&G, and SS.

TABLE 3. USERS OF RECLAIMED WATER - TOLERABLE WATER SUPPLY QUALITY

Constituent	Concentration (mg/L)											
	Laundries*	Recreational Lakes†	Fire Protection/ Spill Washdown Reservoirs	Irrigation***	Boilers	Cooling Waters#	Wet Scrubbers	Wash Racks and Steam Cleaning**	Metal Electro-plating and Finishing†	Metal Cleaning	Paint Booths	Photographic Laboratories
BOD_5	45	10	10	30	1.0		100	10	1	1	30	0.1
COD	500	60	22	60	3.0	75	200	25	3	3	60	1.0
pH (in pH units)	6.0-6.8	5.0-9.0	5.0-9.0	4.5-9.0	>9.0							
TDS	3,300	2,000		2,000	2,000	500-1,500	2,000	2,000	500	500		700
O&G	10	5	1.0	30	0.0		50	5			30	0.2
SS	30	10	10	50	10	100	100	10	1	1	60	1.0
PHNL	0.05	0.01	0.01	0.5	0.1		2.0	2.0	0.001	0.001		0.001
As	0.5								0.05	0.05		
B		0.1	0.1	3	2.0				1.0	1.0		0.1
$CaCO_3$							300	500				400
Cd					20				0.01	0.01		
Cr	0.5								0.05	0.05		
Cu	1.0								1.00	1.00		0.5
CN	0.2	0.1	0.1	0.01	0.5		0.5	0.5	0.2	0.2	0.5	0.01
Cl^-		300		*350*	*200*	*500*	*600*	*600*				200
Fe	1.0	5.0	5.0	10	0.5	0.5	20	40	0.3	0.3		0.3
Mn	1.0				0.5	0.5			0.05	0.05		0.5
Mg							200					
Na		250		350	200		600	600				100
NH_4		0.1	10	20	2.5		20	5	0.5	0.5	15	0.1
NH_3-N	1.5											
NO_3		2.5	5.0				50		10	10		20
Pb	0.5					0.3		1	0.05	0.05		
PO_4		0.3	1		0.3							3.0
Si					50	50						
SO_4						200						
Zn	0.5								5.0	5.0		

TABLE 3 (continued)

Constituent (mg/ℓ)	Laundries*	Recreational Lakes†	Fire Protection/ Spill Washdown Reservoirs	Irrigation***	Boilers	Cooling Waters#	Wet Scrubbers	Wash Racks and Steam Cleaning**	Metal Electro-plating and Finishing	Metal Cleaning	Paint Booths	Photographic Laboratories
Hardness (as $CaCO_3$)	50				10	50			10	10		
ALK (as $CaCO_3$)	60				100	350						
DO	>0	5	3	>0	>0	>0	>0	>0	>0			
Median coliform (No./100 mℓ)	≤ 2.2	≤ 2.2		##				≤ 2.2				
Level of Confidence	1	1	2	1	1	1	3	3	1	1	3	3

*Applies to both industrial laundries and coin-operated laundromats.
†Limited body contact
#Applies to cooling waters for boilers, dynamometers, air compressors, vapor degreasers, and any operation that has a cooling tower.
**Applies to both vehicle and aircraft wash racks
††Rinse waters
##Agricultural irrigation - 2.2/100 mℓ; landscape irrigation - 23/100 mℓ
***Note that some plants are much less tolerant than others to various constituent concentrations and may require water of high quality from that shown in the Table; BOD, TDS, chlorides, and Boron are particularly important in this regard.

AIRCRAFT WASH RACKS

Description

Many Army posts operate and maintain aircraft, either fixed-wing or rotary-wing (helicopters). The maintenance facilities contain wash racks for periodic washing of the aircraft. The magnitude of the washing operation varies greatly from post to post. Most of the wastewater generated is from water used to rinse off solvents and detergents used in the washing operation. Wash and rinse wastewaters are usually collected in floor drains and treated by an oil/water separator before discharge to the sanitary or storm sewer.

Flow

The quantity of wastewater generated depends on the number and types of aircraft washed. Typically, the Army washes each aircraft after every 100 hours of operation. A steady flow of water is used for 20 to 30 minutes per aircraft. In most cases, a 1-1/2-in hose with spray nozzle attachments is used. A mild detergent is added to the water. Average volumes generated are reported to be 300 to 2,500 gal for small size fixed-wing aircraft, and 200 to 1,500 gal per rotary-wing aircraft. Total generation of aircraft washing wastewater at Army posts ranges from 0 to 40,000 gpd.

Tolerable Water Supply Quality

Table 4 summarizes tolerable water supply quality concentrations for aircraft wash rack operations. As with vehicle wash racks, washing of aircraft is done manually. Because workers come in contact with the wash water, fresh water or a high-quality tertiary effluent is needed. To reduce the presence of pathogenic viruses and bacteria in the water, a highly disinfected effluent would be necessary if sewage treatment plant effluent were used.

Typical Effluent Quality

Table 5 summarizes typical effluent quality for aircraft washing operations. As can be seen, the waste is very high in BOD, COD, O&G, and PO_4.

Reuse Potential

Aircraft washing appears to have potential as a recipient of good quality filtered secondary effluent that has been highly disinfected to remove or deactivate bacteria and virus. This level of disinfection is required because of the direct human contact with the water spray. However, if reuse involves treatment and recycling of wash rack wastewater only, then high level disinfection is no longer required and a water higher in solids and other components can be tolerated. In most cases, tertiary

TABLE 4. TOLERABLE WATER SUPPLY QUALITY -- AIRCRAFT WASH RACKS

Constituent	Concentration (mg/L)*
BOD_5	10
COD	25
Phenol	2.0
SS	10
TDS	2,000
O&G	5.0
Cl^-	600
NO_3	†
NH_4	5.0
PO_4	†
Na	600
$CaCO_3$	500
B	†
CN	0.5
Fe	40
MPN (total Coliform Bacteria)	<2.2/100 ml

*All tolerable levels estimated by SCS Engineers, as no literature or base data was available.

†Concentration not significant for this operation (i.e., high concentrations can be tolerated).

TABLE 5. TYPICAL EFFLUENT QUALITY -- AIRCRAFT WASH RACKS

Constituent	Concentration (mg/L)*
BOD_5	5,700
COD	8,400
Phenol	8.5
SS	470
TDS	†
O&G	280
Cl^-	†
NO_3	0.8
NH_4	(0.1)
PO_4	80
Na	†
$CaCO_3$	†
B	(0.1)
CN	(0.005)
Fe	1.1

*Concentration in parentheses estimated by SCS Engineers, other concentrations based on Ref. 4.
†Concentration dependent on source water quality.

treatment is not economically justifiable solely for the purpose of supplying reclaimed water to wash racks. If a highly disinfected tertiary effluent is required for other purposes, then wash racks may be potential users.

Internal Recycling

Wash rack wastewater can be used for internal recycling if the quality of the effluent meets the general criteria set in Table 30. Treatment for internal recycling usually involves settling, grease and oil separation, and filtration. To remove heavy suspended solids and free oil, water from the wash racks would go to settling basins for a detention time of at least 2 hours. Sludge would be pumped off the bottom to holding tanks or beds, while the free oils would be removed by floating oil skimmers. Water from the settling basins would then be pumped over sand filters to remove suspended solids remaining in the wastewater.

The U.S. Army Construction Engineering Research Laboratory in Champaign, Illinois, is studying how to design, build, and operate centralized facilities for tactical vehicle washing (2,3). Treatment of the wastewater by settling, skimming, and intermittent sand filtration has been investigated on a pilot scale. It appears that the effluent would be of high enough quality to be recycled.

Centralization of wash rack facilities increases the feasibility of reuse or recycling, because at a single, large facility, enough water could be used to justify costs for piping, storage, and treatment.

AIR POLLUTION WET SCRUBBERS

Description

Military posts that burn coal for power or steam generation are often faced with the problem of particulate and SO_2 removal. Combined removal of both particulates and SO_2 can be achieved with wet scrubbing techniques. Various types of experimental laboratories also require significant amounts of input water and may be operated in an open or closed loop mode, depending upon the design selected. The amount of water required depends upon the mode of operation and the size of the fuel-burning system.

In the closed loop mode of operation, all input water leaves the system by evaporation or with the sludge (primarily composed of particulate material and/or insoluble SO_2 and SO_3 compounds, i.e., calcium sulfites and sulfates).

Wet collection devices include spray chambers, cyclone scrubbers, orific scrubbers, mechanical scrubbers, mechanical-centrifugal scrubbers, high-pressure scrubbers, venturi scrubbers, packed towers, and wet filters.

Flow

Flows from scrubbers on small power plants will range from virtually zero for a closed loop system (all water being discharged in the sludge) to 40,000 gpd for an open system.

Tolerable Water Supply Quality

The water quality acceptable for use in a wet scrubber depends upon the specific design of the unit and the condition of the input stream. Generally, water of a very poor quality can be admitted except when it is to be utilized in pump seal lubrication and in demister rinse operations (a secondary water usage). Many SO_2 scrubbers have been successfully operated using internal recirculating slurries containing very high concentrations of SS and DS. They have also been operated using soda/lime clarifier sludge as an input water and chemical supply.

In general, well-designed wet scrubbers can accept almost any quality of water if provisions are made to use nonscaling, noncorrosive water for pump seals and demisters. Reclaimed water would have to meet the quality shown in Table 6 in order to be used in wet scrubbers.

Typical Effluent Quality

Effluent quality depends on the number of reuse cycles. Typical concentrations for open-loop operation from U.S. Air Force bases are summarized in Table 7. No Army data were available.

Reuse Potential

Air pollution scrubbers are excellent recipients of treated or untreated wastewater from other activities. The scrubber is tolerant of most other constituents, and its performance is enhanced to some extent by dissolved solids.

Effluents from scrubbers, particularly some types of semi-closed loop systems, are concentrated and usually unsuitable for cascade purposes in other activities. However, in some cases where large quantities of SO_2 are entrained in the scrubber waters at power generation plants, this SO_2 can be used to reduce hexavalent chromium to trivalent chromium at the plating shop pretreatment facility.

Internal Recycling

Most scrubbers operate on a closed-cycle principle, using the water continuously until it is highly contaminated. A portion of the wastewater may be regularly wasted and replaced with

TABLE 6. TOLERABLE WATER SUPPLY QUALITY, AIR POLLUTION WET SCRUBBERS

Constituent	Concentration* (mg/L)
BOD_5	100
COD	200
Phenol	2.0
SS	100
TDS	2,000
O&G	50
Cl^-	600
NO_3	50
NH_4	20
PO_4	†
Na	600
$CaCO_3$	300
B	†
CN	0.5
Fe	20
Mg	200

*All concentrations estimated by SCS Engineers.
†Concentration not significant for this activity.

TABLE 7. TYPICAL EFFLUENT QUALITY, AIR POLLUTION WET SCRUBBERS

Constituent	Concentration (mg/L)*
BOD_5	10
COD	720
Phenol	(0.001)
SS	3,270
TDS	(5,000)
O&G	0.3
Cl^-	(400)
NO_3	(28)
NH_4	(0.1)
PO_4	5.4
Na	(72)
$CaCO_3$	(200)
B	(0.1)
CN	(0.005)
Fe	5.3

*Concentrations in parentheses are SCS Engineers's estimates; other concentrations are from Ref. 4.

fresh water to maintain a concentration equilibrium. The blowdown is of insufficient volume and of such poor quality that onsite treatment and reuse are not feasible.

BASE HOUSING

Description

Almost all posts provide family housing consisting of single family, duplex, and/or multi-unit dwellings (on some posts, mobile homes as well) for officers and enlisted personnel and their families. Apartment type quarters for bachelor officers (BOQ's), visiting officers (VOQ's), and troop barracks for unmarried enlisted personnel are also provided.

Wastewater from family housing areas is produced by dishwashing, toilet use, bath/shower/sink use, clothes laundering and garbage grinding. Wastewater from troop housing is produced by toilet use, bath/shower use, and general area cleanup. In both situations, personal hygiene is the principal source of wastewater.

Flow

The Army typically uses a design figure of 75 gallons per capita per day (gpcd) as the anticipated average domestic sewage flow from post residential areas. The total average daily domestic sewage flow is calculated by multiplying the average per capita figure by the number of dwellings times the estimated average persons per dwelling unit. The design assumptions used are conservative and result in an estimated average flow volume greater than the actual, providing a built-in safety factor for sewer capacity design purposes.

Wastewater generated by BOQ's and VOQ's is generally estimated at approximately 35 to 45 gpcd. Wastewater generated by the barracks averages approximately 25 gpcd.

Tolerable Water Supply Quality

The water supply quality for base housing should meet the National Interior Primary Drinking Water Regulations (NIPDWR) (5). Table 8 lists some of these limits.

Typical Effluent Quality

Table 9 summarizes the effluent from residential base housing as measured at the inlet to the STP. Significant differences can occur between posts as a result of water use habits, groundwater infiltration into sewer lines, the prevalence of garbage grinders, and other factors.

Inorganic constituent concentrations in the wastewater are dependent upon the concentration of those constituents in the

TABLE 8. NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

	Constituent	Maximum Limit (mg/L)*
	Phenol	0.001
	Cyanide	0.2
	Cadmium	0.01
	TDS	500
	Chlorides	250
	Sulphates	250
	Chromium (Total)	0.05
	Copper	1.0
	Iron	0.3
	Lead	0.05
	Manganese	0.05
	Nitrate (as N)	10
	Zinc	5.0
	Arsenic	0.05
	Barium	1.0
	Mercury	0.002
	Selenium	0.01
	Silver	0.05
(a)	Chlorinated hydrocarbons Endrin (1,2,3,4,10. 10-hexachloro-6.7-epoxy-1,4,4a,5,6, 7,8,8a-octahydro-1,4-endo, endo-, endo-5,8 - di-methano naphthalene).	0.0002
	Lindane (1,2,3,4,5,6-hexachloro-cyclohexane, gamma isomer).	0.004
	Methoxychlor (1,1,1-Trichlorothane 2, 2 - bis [p-methoxyphenyl])	0.1
	Toxaphene ($C_{10}H_{10}Cl_8$-Technical chlorinated camphene, 67-69 percent chlorine).	0.005
(b)	Chlorophenoxys: 2,4-D, (2,4-Dichlorophenoxyacetic acid).	0.1
	2,4,5-TP Silvex (2,4,5-Trichloro-phenoxypropionic acid).	0.01

*Ref. 5,6.

TABLE 9. TYPICAL BASE HOUSING SEWAGE CHARACTERISTICS

Constituent	Concentration (mg/L)
BOD_5	200
COD	300
Phenol	0.15
SS	300
TDS	300*
O&G	50-100
Cl^-	100*
NH_4	30
PO_4	10
Na	50*
$CaCO_3$	80*
B	1.0*
CN	0.01
Fe	1.0*
Alk (as $CaCO_3$)	50-100
Total Coliforms per 100 ml	$1x10^6$-$4.6x10^7$

*Plus source water concentration.

source water supply, plus those added incrementally by domestic household use of the freshwater.

Reuse Potential

Currently, potable wastewater reuse is not accepted in the United States. Therefore, family housing, BOQ's, and barracks on Army posts cannot be considered potential users of reclaimed water. However, after secondary or tertiary treatment, the large volume of wastewater generated from post housing would be an excellent potential source of water for reuse in other subpotable activities.

Internal Recycling

Potable wastewater recycling for post housing is not currently feasible either from the standpoint of public health or economics.

However, work on systems to recycle greywater (domestic wastewater without the toilet component) for toilet flushing and landscape irrigation is continuing, and systems are currently online in some locales. These technologies are capable of reducing wastewater generation by approximately 40 percent in the typical home. The costs of such systems would normally preclude their use in all but the most critical water short locations.

UNCLASSIFIED OFFICE SPACE

Description

Unclassified office space is limited to office facilities only (i.e., does not include laboratory spaces) and includes: headquarters and various tenants.

Flow

Wastewater generated by office facilities averages from 10 to 25 gal per person per day.

Tolerable Water Supply Quality

See Base Housing.

Typical Effluent Quality

See Base Housing.

Reuse Potential

See Base Housing.

Internal Recycling

See Base Housing.

COMMERCIAL SERVICES

Description

Army posts are essentially small cities, and, as such, they require commercial services. These include: service stations, theatres, bowling alleys, PX's, commissaries, etc.

Flow

Wastewater generated by commercial services is domestic in quality and usually of negligible volume. It can be assumed that the domestic volumes previously discussed adequately include the volume generated by commercial activities.

Tolerable Water Supply Quality

See Base Housing.

Typical Effluent Quality

See Base Housing.

Reuse Potential

See Base Housing.

Internal Recycling

See Base Housing.

BOILERS

Description

Facilities that use boilers include: gas-, coal-, or oil-fired electric power and heating plants, nonindustrial steam power plants, and certain types of heating and air conditioning plants.

Flow

Wastewater generated consists of continuous or intermittent blowdown that will vary in quality depending on the size of the boiler facility, the mode of operation, the quality of the source water (TDS, hardness, etc.), and the type of boiler maintenance chemicals used. An average blowdown volume at a moderately sized boiler plant for heating ranges from approximately 2,000 gpd to

10,000 gpd. If air conditioning and/or power generation is also done at the plant, the blowdown may increase to 50,000 to 100,000 gpd, or more.

Tolerable Water Supply Quality

The technology of boiler feedwater makeup waters is complex, as evidenced by the large number of major U.S. corporations which specialize in providing consulting and chemical supply services for treatment of this water. In general, the more contaminated the raw water supply, the more difficult it is to treat the water to render it noncorrosive and non-scale forming.

Water quality requirements for boilers vary depending on the operating pressure. For the purposes of this report, we have assumed that low-pressure boilers (200 to 400 psig) are being used for heating and/or power generation. Even low-pressure boilers require water of low hardness to reduce scaling of pipes and heat exchange units. Table 10 summarizes water quality for low-pressure boilers.

Final Effluent Quality

Closed loop boiler systems concentrate contaminants in the source water roughly 5 to 10 times before discharge, due to evaporative loss. Chemicals commonly added to the boiler feedwater include tannin, sodium hydroxide, sodium sulfite, hydrazine, polymers, and phosphates. Corrosion and algae inhibitors containing heavy metals (Cu, Ni, and Cr) are also added. Table 11 shows typical discharge concentrations. The effluent will tend to be high in TDS, hardness, dissolved salts, and perhaps nutrients, depending on the source water concentrations for these constituents.

Reuse Potential

High quality demands for boiler feedwater makeup systems normally preclude the feasible use of reclaimed water for this purpose; however, there are three locations, all in western Texas, where reclaimed municipal effluent is subjected to extensive additional treatment and used for boiler feedwater makeup. In all three cases, the existing freshwater supplies are severely limited. Because of economies of scale, it is doubtful that an Army installation could justify the cost of the treatment facilities and chemicals to further treat reclaimed effluent to a level commensurate with alternate freshwater supplies.

Boiler blowdown is usually high in TDS, but is one of the few activity effluents which may be suitable for direct reuse without further treatment. Reuse of boiler blowdown may be feasible in activities for which salts are not a problem (e.g., paint shop water wall, air pollution control scrubber, or irrigation waters after blending).

TABLE 10. TOLERABLE WATER SUPPLY QUALITY - LOW PRESSURE BOILERS

Constituent	Concentration (mg/L)*
BOD_5	(1.0)
COD	(3.0)
Phenol	(0.1)
SS	(10)
TDS	2,000††
Hardness ($CaCO_3$)	10
O&G	(0.0)
Cl^-	(200)
NO_3	†
NH_4	(2.5)
PO_4	(0.3)
H_2S	0.0
Na	(200)
CO_3	40
B	(2.0)
CN	(0.5)
Fe	(0.5)
Mn	(0.5)
Si (as SiO_2)	(50)
Alk (as $CaCO_3$)	(100)
pH	>9.0

* Concentrations in parentheses are SCS Engineers's estimates; other values based on Ref. 9.
† Concentration not significant for this activity.
††Depends on boiler design.

TABLE 11. TYPICAL EFFLUENT QUALITY -- LOW PRESSURE BOILERS

Constituent	Concentration (mg/L)*
BOD_5	5.0
COD	15
Phenol	0.5
SS	50
TDS	3,500
O&G	0.5
Hardness ($CaCO_3$)	50
Cl^-	1,000
NO_3	150
NH_4	2.0
PO_4	60
Na	1,000
CO_3	200
B	10
CN	2.5
Fe	2.5
Mn	2.5
Zn	1.0
Si	2.5
Ni	0-0.1
Cu	3.0
Alk (as $CaCO_3$)	500
Cr	0.005
pH (units)	10.0

*All concentrations represent 5 times tolerable source water quality limits except PO_4, Cu, Cr, Zn, and Ni.

Internal Recycling

Boiler blowdown water could conceivably supply some of the other water-consuming activities which take place in boiler facilities. Specifically, a portion of it could be used as maintenance cleaning water, stack scrubber water, or ash-handling system water. Boiler blowdown water could be reused as boiler feed only after extensive treatment that is not economically justifiable.

COOLING TOWERS

Description

Cooling towers are normally used with any large air conditioning, heating, power generation or other heat transfer operation (e.g., vapor degreasers, dynamometers, air compressors, autoclaves). The two basic types of cooling towers are single-pass and recirculating towers. A single-pass system uses water from a surface or ground water source which is pumped, heated, cooled by evaporation, and discharged to surface or ground water. A recirculating system repeatedly cools and reuses water. In order to maintain a stable dissolved solids concentration in the cooling tower, water from the tower must be wasted (called blowdown) and replaced with makeup water. In addition to replacing blowdown, this makeup water must replace water lost by evaporation, wind drift, and leakage.

Blowdown can be continuous or periodic. The frequency and amount of blowdown depend on the maximum dissolved solids concentration, the dissolved solids concentration of the source water, and the rate of evaporation in the system.

Flow

As mentioned above, the frequency and volume of blowdown depend on many factors.

As a general approximation, the following flow factors are presented for a 100-ton cooling tower:

- Recirculation rate: 300 gpm
- Evaporation loss: 4.8 gpm
- Drift loss: 0.6 gpm
- Leakage loss: 0.3 gpm
- Blowdown: 1.5 gpm
- Make-up water required: 7.2 gpm.

Thus, the flows to and from a 100-ton cooling tower are significant alone. However, a base with many such towers can have a large total demand for cooling water.

Tolerable Water Supply Quality

Cooling waters should be cool in temperature, and should not deposit scale, be corrosive, or encourage the growth of slimes. Among the constituents of water that may prove detrimental to its use for cooling purposes are hardness, suspended solids, dissolved gases, acids, oil, organic compounds, and slime-forming organisms.

The water quality requirements for cooling waters depend upon the type of system, recirculating or once-through. Quality requirements for cooling waters in recirculating systems are given in Table 12. Water quality requirements for once-through cooling are considerably less stringent. The primary quality concerns are, (1) excessive nutrients stimulating biological activity and producing slime growth in the cooling system; and (2) potential deposits from suspended matter in the water. Except in unusual situations, the scaling and corrosion problems, which are large concerns in recirculating systems, are not important considerations in once-through systems. Water quality requirements for once-through cooling waters are estimated in Table 13.

Seawater and other waters high in TDS and turbidity are commonly used is single-pass systems, but would cause severe problems in recirculating systems.

Final Effluent Quality

Recirculating cooling tower systems concentrate contaminants roughly five time before blowdown due to evaporation. Table 14 shows typical discharge concentrations. As shown, the effluent will tend to be high in TDS, hardness, and dissolved salts. Minerals and nutrients may be present in high concentrations depending on source water concentrations for these constituents.

Reuse Potential

There are many locations in the United States where municipal sewage effluent is further treated and used for cooling water makeup at large power generation facilities. Cooling towers are a major potential user of reclaimed wastewater. In addition, the wastewater discharged from the cooling towers could be utilized for reuse at some other low water quality activities, such as paint shop water walls, air pollution control scrubbers, and wash down operations.

Internal Recycling

One way to achieve recycling is to convert a single-pass cooling tower system to a recirculating system. The feasibility of this approach would depend on the source water quality and the system design.

TABLE 12. TOLERABLE WATER SUPPLY QUALITY - COOLING WATERS IN RECIRCULATING SYSTEMS

Constituent	Concentration (mg/L)*
BOD_5	10
COD	75
Turbidity	50
SS	100
TDS	500-1,500
Total P	0.3
Hardness ($CaCO_3$)	50
Fe	0.5
Mn	0.5
Si (as SiO_2)	50
Al	0.1
Ca	50
HCO_3	24
SO_4	200
Cl^-	500
Alk (as $CaCO_3$)	350
MBAS	1.0

*Ref. 9, 10.

TABLE 13. TOLERABLE WATER QUALITY - ONCE-THROUGH COOLING WATERS

Constituent	Concentration (mg/L)*
SS	100
Total P	1.0
Hardness ($CaCO_3$)	650
Fe	0.5
Mn	0.5

*All concentrations estimated by SCS Engineers. Constituents that are not listed are not critical for this activity.

TABLE 14. TYPICAL EFFLUENT QUALITY - COOLING TOWER BLOWDOWN

Constituent	Concentration (mg/L)*
Alkalinity ($CaCO_3$)	†
BOD_5	7.0
COD	35
Phenol	0-0.1
SS	30
TDS	†
Cl^-	†
P (tot)	2.1
Hardness ($CaCO_3$)	†
Fe	0.6
SO_4	†
Cu	0-2.0
Cr	0.05
Mn	0.1
Zn	3.0
Ni	1.0
pH	7.4

*Ref. 8, 11.

†Depends on source water concentration, recirculation cycles, and blowdown volume. For a typical recirculating cooling tower, this constituent concentration will be about 5 times the source water concentration.

DYNAMOMETERS

Description

Engine and transmission testing facilities usually contain one or more dynamometers, instruments used to test and adjust engines or transmissions under various loads. Since the dynamometers generate a great amount of waste heat, they are water cooled. The hot wastewater may be discharged directly, or cooled first in a pond or tower. If a cooling tower is used, it may be either a once-through or recirculating type.

Flow

Three dynamometers used for tuning rebuilt tank transmissions at Anniston Army Depot use an estimated 11,000 gpd each on a single-pass basis. (Each dynamometer is operated approximately 4.5 hours per day.)

Anniston also has 20 engine-testing dynamometers, with the effluent from these passing through a recirculating cooling tower system. The flow to the system consists of makeup water added to replace evaporation, wind drift, and blowdown losses. The effluent consists of blowdown from the cooling tower system.

The Corpus Christi Army Depot operates nine dynamometers and water-brake systems for stressing and cooling rotary wing aircraft engines and transmissions. Water from each test cell is recycled through a large cooling tower. The entire transmission and engine test facility requires 450 tons of cooling.

Tolerable Water Supply Quality

Water used for cooling of dynamometers should be low in total and dissolved solids, noncorrosive and non-scale forming. Tolerable water quality requirements are the same as those listed for cooling waters in Tables 12 and 13.

Typical Effluent Quality

In a once-through system, the effluent quality is closely related to the source water quality. During use, small increments of suspended and dissolved solids are added. If the water is recycled through a recirculating cooling tower, however, the pollutants are concentrated several times by evaporation. For typical blowdown quality, see Table 14.

Reuse Potential

The potential exists for use of reclaimed wastewater of low suspended and dissolved solids concentrations in dynamometer facilities. In addition, the wastewater discharged from this activity could be utilized for reuse at activities not sensitive to high salt concentrations.

Internal Recycling

Internal recycling of dynamometer cooling water is possible with a recirculating cooling tower system. Recirculating systems are usually preferred over the once-through type because of the tremendous savings in water.

FIRE PROTECTION/SPILL WASHDOWN RESERVOIR

Description

Most industrial bases (depots) must provide storage of large volumes of water for fire protection and for washdown of oil and fuel spills.

Flow

It is assumed that the reservoir is kept full and refilled as needed to make up for evaporative losses. It could also be used as an irrigation water buffer.

Tolerable Water Supply Quality

Table 15 lists tolerable water quality limits for fire protection/spill washdown reservoirs.

Typical Effluent Quality

No discharge.

Reuse Potential

These reservoirs would be excellent recipients for secondary effluent. Although they are filled infrequently when used for fire protection alone, these reservoirs would also be used to store reclaimed water for the reuse system.

HOSPITALS/CLINICS

Description

Wastewater from hospitals comes primarily from patients' bath/shower and toilet use, kitchen, laundry, and laboratory activities, and heating/cooling plants.

Wastewaters from hospitals contain BOD, COD, and TSS concentrations comparable to normal domestic sewage, and are amenable to biological treatment.

Specific contaminants which may appear in hospital wastewater include Hg, Ba, Be, and B. Mercury is used primarily in hospital laboratories, but also appears in various forms in medicines, disinfectants, and mildew inhibitors. Broken thermometers

TABLE 15. TOLERABLE WATER SUPPLY QUALITY -- FIRE PROTECTION/SPILL WASHDOWN RESERVOIRS

Constituent	Concentration (mg/L)*
BOD_5	10
COD	22
Phenol	0.01
SS	10
TDS	†
O&G	1.0
Cl^-	†
NO_3	5.0
NH_4	10
PO_4	1
Na	†
$CaCO_3$	†
B	0.1
CN	0.1
Fe	5.0
pH	5.0-9.0

*All concentrations estimated by SCS Engineers.
†Concentration not significant for this activity.

are also a source of Hg. Silver contamination comes from spent developer solutions discarded by hospital x-ray departments. Boron is another contaminant which may appear in x-ray department wastes. This element is found in fixer solutions used in automatic film processing equipment. Barium injections are used for diagnostic purposes, and this metal may appear in a hospital's sanitary wastes. Beryllium is often used in dental laboratories and may appear in hospital wastewater.

Flow

Wastewater generated by hospitals and clinics averages approximately 300 gal per bed per day.

Tolerable Water Supply Quality

See Base Housing.

Typical Effluent Quality

Table 16 summarizes Army hospital wastewater characteristics. In addition to metal concentrations, hospital wastewater can differ from domestic wastewater in that it may contain higher concentrations of pathogenic viruses and bacteria.

Reuse Potential

See Base Housing.

Internal Recycling

The Army Medical Bioengineering Research and Development Laboratory has done extensive pilot-scale testing of mobile treatment units capable of treating hospital wastewater for direct, potable use (7). The required treatment is very sophisticated and expensive, and is justified only under combat conditions where water is extremely scarce and valuable. At fixed Army installations, such treatment is not justified.

IRRIGATION

Description

Many bases irrigate golf courses, athletic fields, landscaped areas, parade grounds, and housing areas. In semi-arid locations, irrigation is usually the major water user on the base during the summer. Irrigation with treated municipal sewage effluent can be considered an established technology, with approximately 300 such applications in operation in the United States, including over 40 at golf courses.

TABLE 16. TYPICAL EFFLUENT QUALITY -- HOSPITALS

Concentration	Concentration (mg/L)*
BOD_5	250
COD	850
SS	200
TDS	1,400
O&G	45
PO_4 (as P)	170
Sulfate	35
Turbidity, JTU	50
Alkalinity ($CaCO_3$)	125
ABS (measure of detergents)	75
Cd	0.02
Ca	15
Cr	1.1
Fe	0.3
Pb	0.3
Mg	16
Potassium (K)	34
Na	360
Silver (Ag)	0.3
pH	7.6

*Ref. 8.

Flow

It is assumed that no water is discharged from irrigated grounds, and that irrigation demand will vary tremendously depending on climatic conditions. Potential irrigation reuse applications in semi-arid areas are often greater than the total wastewater production of the base.

Tolerable Water Supply Quality

Table 17 lists tolerable quality limits for irrigation water applied to golf courses. Of particular importance are BOD, chlorides, and TDS. Note that some plants are much less tolerant than others to various constituent concentrations, and may require water of higher quality than that shown in the table.

Typical Effluent Quality

No discharge.

Reuse Potential

Golf courses and other irrigation areas are excellent recipients (sinks) for reclaimed wastewater if satisfactorily treated. Nutrients in the wastewater are an advantage as fertilizer. Where concentrations of certain constituents are intolerable or borderline, intelligent irrigation management and/or blending with freshwater supplies will provide satisfactory solutions.

LAUNDRIES

Description

Most U.S. Army troop and training installations have large, central laundry facilities for washing military-related articles, such as uniforms, work clothes, sleeping bags, bedding, towels, and tablecloths. Personal clothing and other personal articles are washed at coin-operated laundromats.

Flow

The large, industrial-type laundries contain washers which hold up to 600 lb of clothing and fill with water up to seven times per washing cycle. Water consumption is large: data from Fort Ord show that their industrial laundry uses an average of 30,000 gal of water per day; at Fort Jackson, 40,000 to 60,000 gal per day are used. The Fort Ord laundry uses an average of four gal of water per item laundered. On a weight basis, industrial laundries use an average of 5.6 gal per pound of clothes laundered (8). The wastewater flow from this type of laundry may

TABLE 17. TOLERABLE WATER SUPPLY QUALITY -- IRRIGATION

Constituent	Concentration (mg/L)*
BOD_5	30
COD	60
Phenol	0.5
SS	50
TDS	2,000
O&G	30
Cl^-	350
NO_3	10#
NH_4	20
PO_4	†
Na	350
$CaCO_3$	†
B	3.0
CN	0.01
Fe	10
pH	4.5-9.0
Media coliform number	
- agricultural irrigation	2.2/100 ml
- landscape irrigation	23/100 ml

*All concentrations are SCS Engineers's estimates based on water quality of existing irrigation reuse programs, and generally constitute maximums for hardy turf applications. Many plants may have a lower tolerance to certain constituents (e.g., boron) than listed here.

#Is significant only if danger of potable ground water contamination.

†Concentrations not significant for this activity.

vary significantly due to vacation and holiday periods or extensive field training exercises. Normally, these laundries are in operation 8 to 16 hours per day, 5 days per week.

The quantity of wastewater produced by a coin-operated laundromat is a function of the frequency of machine use. Most laundromats contain 25 to 35 machines, each of which uses 30 to 40 gallons per wash. Wastewater is usually generated 24 hours per day, 7 days per week. Variations in wastewater flow occur due to vacation and holiday periods, weather conditions, day of the week, and field training exercises.

Tolerable Water Supply Quality

The most detrimental constituent in water used for laundering is hardness, because it increases soap usage and curd formation. In addition, the presence of iron and manganese, even in low concentrations, can cause stains on the materials being laundered. A summary of tolerable water supply concentrations for laundries is presented in Table 18.

Typical Effluent Quality

Wastewater from laundries contains grease, oil, dirt, and dyes removed from clothes; and soap, detergents, bleach, brighteners, and other agents used in the cleaning process. The quality of laundry wastewater can vary widely depending upon the condition of the materials being washed. Industrial laundry wastewaters can contribute anywhere from 1 to 20 times as much contamination as the average domestic wastewater. They tend to be high in alkalinity, turbidity, and color. They often have a BOD_5 of at least twice that of domestic sewage and contain heavy metals. As an extreme example, a certain nonmilitary industrial laundry produced wastewater with 5,600 mg/L SS, 41,000 mg/L TS, and 15,000 mg/L O&G. An industrial laundry on an Army post would produce a much weaker wastewater with characteristics closer to those in Table 19.

Laundromat effluents are in general less contaminated than industrial laundry effluents. Table 20 summarizes typical effluent quality for coin-operated laundromats.

Reuse Potential

Laundry wastewater is too heavily contaminated to allow direct cascade to another activity without pretreatment. However, after extensive pretreatment, or after treatment in an existing sewage or industrial waste treatment plant, laundry wastewater could potentially be reused for irrigation or other activities.

At this time, it is probably not socially acceptable to use sewage treatment plant or industrial waste treatment plant effluent in a laundry. In addition, there are no accepted quality

TABLE 18. TOLERABLE WATER QUALITY -- LAUNDRIES

Constituent	Concentration (mg/L)*
BOD_5	45
COD	500
Phenol	0.05
O&G	10
SS	30
TDS	3,300
NH_3-N	1.5
Hardness ($CaCO_3$)	50
Alkalinity ($CaCO_3$)	60
Fe	1.0
Mn	1.0
Zn	0.5
Cr	0.5
Cu	(1.0)
CN	(0.2)
As	(0.5)
Pb	0.5
Median coliform number	($\leq$ 2.2/100 mℓ)
pH	6.0-6.8

*Concentrations in parentheses estimated by SCS Engineers; other data from Ref. 9, 12, 13 and 14.

TABLE 19. TYPICAL EFFLUENT QUALITY -- INDUSTRIAL LAUNDRY

Constituent	Concentration (mg/L)*
BOD_5	450
COD	2,000
SS	1,000
TDS	2,000
O&G	300
Alkalinity ($CaCO_3$)	500
Fe	1.0
Si	130
Ca	740
Mg	6.4
Cu	0.3
Pb	0.7
Cd	0.04
Zn	0.5
Cr	0.06
Ni	2.1
Hg	0.001-0.007
pH	11.2

*Ref. 8, 11, 12, 13, 14, and 15.

TABLE 20. TYPICAL EFFLUENT QUALITY -- LAUNDROMAT

Constituent	Concentration* (mg/L)
BOD_5	200
COD	400
SS	130
TDS	360
O&G	750
PO_4	220
NH_3-N	3.0
NO_3	1.0
$CaCO_3$	250
Detergent (ABS)	60
Turbidity	250
pH	8.2
Alkalinity ($CaCO_3$)	182

*Ref. 8 and 14.

standards for supply water to laundries. However, internal recycling within a laundry has excellent potential for application at Army laundry facilities, as discussed below.

Internal Recycling

Commercial laundry water recycling systems are available. In some of these systems, only a portion of the laundry wastewater is recycled. The relatively clean wastewater from the last rinse is reused in the wash and the early rinses; freshwater is still supplied to the last rinses. This type of counter-current washing involves only equalization and new plumbing. No treatment is required.

Total recycling of all the process waters is achieved by some available recycling systems. The treatment requirements include treatment with a germicide and de-emulsifier, chemical coagulation, dissolved air flotation, and mechanical filtration (11, 14).

Laundry water recycling systems could be economical for both industrial laundries and laundromats on Army posts. They can cut costs for fuel, chemicals, water, and sewer charges.

METAL CLEANING

Description

Vehicle and equipment maintenance, repair, and rebuilding are common activities on Army posts. Some posts are heavily involved in the disassembly and cleaning of engines and transmissions. The equipment is disassembled and metal parts are cleaned in several small individual operations, including:

- Steam cleaning
- Paint stripping
- Carbon stripping
- Corrosion removal
- Vapor degreasing
- Industrial washers
- Bright dipping
- Hot and cold water rinses.

Individually, these operations are insignificant water users; however, when they are located together in a single area, the waste streams are often combined to create a flow of several thousand gal per day.

Flow

The flow rate to and from a metal cleaning area is highly variable, since the various operations are performed on an irregular basis as they are needed. During operation, a trichloroethylene vapor degreasing unit typically has a cooling water flow

of 5 to 10 gpm, while an industrial washer uses an estimated 50 gpm. Running hot and cold water rinse tanks typically overflow at about 8 gpm.

At Letterkenny Army Depot, the flow rate from the engine disassembly and cleaning area was found to range from 23 to 100 gpm. Even during nonoperating hours, the flow did not drop below 23 gpm (16). At Red River Army Depot, there was a continuous background flow of wastewater from the maintenance area. Sources of the 188 gpm background flow were the continuous water uses in the maintenance area such as running rinses, cooling water for vapor degreasers, and scrubbing devices for control of cyanide, chromium, and particulates in ventilation air flows (17).

Tolerable Water Supply Quality

The water quality necessary for hot water rinses is similar to that required for rinse tanks in metal electroplating and finishing operations (see Table 22). The water must be of low hardness and dissolved solids. Water used in vapor degreasing is circulated through cooling coils and, therefore, should be non-corrosive and nonscaling. For acid stripping or for alkaline cleaning, the quality of water used in the baths is less critical, since the added chemicals far outweigh the natural constituents of the water. Excessive hardness should be avoided, however. Assuming that a single water supply is to be used for all of these operations, the water should be of a very high quality.

Typical Effluent Quality

Chemicals used in the various metal cleaning operations include various solvents and detergents, phosphoric acid, sodium hydroxide, and magnesium chromate. Typically, the waste stream is highly contaminated, containing suspended solids, oil and grease, carbon, phosphates, ammonia, MBAS, phenol, zinc, iron, lead, aluminum, chromium, and compounds such as orthodichlorobenzene, methylene chloride, and trichloroethylene. The pH and alkalinity are usually high. Table 21 shows typical effluent concentrations for several parameters.

Reuse Potential

Little potential for direct cascade to or from metal cleaning exists. The requisite water quality for the activity is high; the volume of use is relatively small; and the waste stream is highly contaminated. All of these factors are unfavorable for direct reuse. The wastewater is a heavily contaminated industrial waste which is difficult to treat, thus, indirect reuse is possible only with a sophisticated industrial waste treatment scheme and, possibly, dilution with higher quality water.

TABLE 21. TYPICAL EFFLUENT QUALITY -- METAL CLEANING

Constituent	Concentration (mg/L)*
COD	3,000
SS	300
O&G	350
Phenol	70
PO_4	40
CN	0.6
Pb	0.4
Zn	6.0
Cr	25
Cd	0.5
pH	9.0
Alkalinity ($CaCO_3$)	400
MBAS	3.0

*Ref. 18,23.

Internal Recycling

These wastes are most easily treated at a centralized IWTP designed to handle "problem" wastes. However, such low-volume, high-contamination wastes can provide a good opportunity for waste pretreatment and internal reuse if the pollution control aspects of the waste are creating a problem. For example, counter-current rinse systems and material recovery systems present opportunities for internal reuse before the wastes are mixed.

METAL ELECTROPLATING AND FINISHING

Description

Metal electroplating and finishing processes are involved in the repair and maintenance of engines, equipment, weapons, vehicles, and rotary- and fixed-wing aircraft. Army installations with repair and maintenance operations usually have plating facilities. Each facility is unique, and the processes used and the makeup of processing solutions are highly variable. The processing equipment employed, the production volume, and the type and shape of the articles to be processed also differ from facility to facility. Plating materials include Cr, Mn, Zn, Cu, Cd, Ni, Ag, Au, and CN.

Flow

The volume of wastewater generated by plating and finishing operations varies tremendously in the range of 15,000 to 250,000 gpd, depending on the size and water management practices of the shop. A typical overflow rate for a single cold water rinse tank is 10 gpm, while that for a hot water rinse tank is 2 gpm. This can vary depending on operating procedures and water saving attitudes. For example, the plating shop rinse tanks at the Corpus Christi Army Depot were all retrofitted with conductivity waters and automatic shut-off valves. Thus, new water was added only when the tank salt content reached a certain level. Overflow volumes were cut drastically compared to the original continuous overflow procedure. In addition, plant engineers estimated a savings of $5,000/tank/yr in fuel cost for each hot rinse tank due to the conductivity controls.

Tolerable Water Supply Quality

Water quality limits for plating depend on the type of plating being performed, and on the particular operation receiving the water. Water from the potable supply or deionized water is required for rinse tanks, plating baths, and scrubbers, which together represent approximately 80 percent of the activity water demand. Washdown is the only low quality water use in the plating operation; it comprises approximately 20 percent of the total water demand.

TABLE 22. TOLERABLE WATER SUPPLY QUALITY -- METAL ELECTROPLATING AND FINISHING RINSE WATERS

Constituent	Concentration (mg/L)*
BOD_5	1.0
COD	3.0
TDS	500
SS	1.0
Phenol	0.001
Hardness ($CaCO_3$)	10
As	0.05
B	1.0
Cd	0.01
Cr	0.05
Cu	1.0
CN	0.2
Fe	0.3
Mn	0.05
NH_4	0.5
NO_3	10
Pb	0.05
SO_4	5.0
HCO_3	5.0
Zn	5.0

*All concentrations estimated by SCS Engineers.

later treatment stages. Chemical contaminants are more concentrated in the wastewater as a result, and are thus easier to treat.

Modifications which provide water for internal reuse include:

- Ion exchange concentration of chemical contaminants in rinse waters, enabling the recovery of valuable metals and yielding deionized water that is useful in rinse tanks and in preparing new solutions.

- Evaporative concentration of chemical contaminants in rinse waters with metal salt recovery, and reuse of water condensed from the steam in rinse tanks.

- Use of an "integrated treatment" system (19): after being removed from the plating bath, metal parts are rinsed with chemicals which remove dragout before a final rinsing with fresh water. The chemical rinse is treated and recirculated, while the freshwater rinse remains uncontaminated and can be 80 to 90 percent reused.

- Recirculation of water in air pollution fume scrubbers.

A study conducted at the electroplating shop at the Oklahoma City Air Logistics Center illustrates the excellent potential for water reuse (20). At this facility, an existing ion exchange system is used to remove dissolved solids from raw water used as makeup water, and from rinse water in plating operations. The wastewaters, including washdown water, dragout from tanks, and rinse tank overflows, were found to contain small amounts of SS, metals, and cyanides. By making relatively minor adjustments, these flows could be passed through in-line, sand- or cartridge-type pressure filters for removal of SS, and then treated by the existing ion exchange system. The ion exchange system could easily remove the metals and cyanide from these waste flows, providing a deionized water suitable for reuse. The wastewater would actually become the source water for the entire electroplating facility, reducing raw water usage by 90 percent.

The deionized water could also be used in the air pollution fume scrubbers. The scrubbers are located on the chrome plating tanks and cyanide tanks. Presently, raw water is used in the scrubbers on a once-through basis, and accumulates 1.0-2.0 mg/L of either chrome or cyanide. However, there is evidence that chrome concentrations as high as 30,000 mg/L in a recycled scrubber water do not significantly affect pollution abatement (20). Therefore, a high recycle ratio is possible, and scrubber effluent can be routed to the ion exchange system for reuse. By using deionized water, sealing problems can also be reduced.

Another internal treatment/reuse facility has just been constructed at the Corpus Christi Army Depot. This operation

collects rinse tank overflow waters and provides the following treatment:

- Chromium: Approximately 100 gpm of chromium rinse tank water is treated by a sand filter, SO_2 addition, and flocculation with polymer addition. Ultimately, this water will be recirculated to the plating rinse tanks.

- Cyanide: Cyanide rinse waters are treated by chlorination and discharged to the IWTP.

PAINT BOOTHS

Description

All posts provide facilities for spray painting. A typical paint area consists of a series of paint booths where vehicles, fixed- and rotary-winged aircraft, and other support equipment are maintained, and overhauled.

A recirculating water wall is operated during painting to scrub the air and entrain any paint particles that have not adhered to the piece of equipment being painted.

Flow

Paint booths at Army posts generate wastewater as blowdown from the water walls. In most cases, the water in a booth is drained and replaced about once a month. The amount of water discharged from a single booth ranges from 200 to 8,000 gal, depending on the size of the booth. Usually, the wastewater is drained to a sewer, and the sludge remaining in the system is drummed and hauled away. Many of these water walls are treated with chemicals to aid in the precipitation and settling of paint flue so that the clarified water can be used for a longer period of time.

Tolerable Water Supply Quality

Water for paint booth water walls need not be of high quality. Table 23 summarizes the water quality requirements for paint booth water walls.

Typical Effluent Quality

Table 24 delineates typical effluent quality for discharges from paint booths. As can be seen, the waste is very high in BOD, COD, O&G, and MBAS. Use of chromate-based and phenolic-based paints contributes hexavalent chromium and phenol to the wastewater.

TABLE 23. TOLERABLE WATER SUPPLY QUALITY -- PAINT BOOTH WATER WALLS

Constituent	Concentration (mg/L)*
BOD_5	30
COD	60
Phenol	†
SS	60
TDS	†
O&G	30
Cl^-	†
NO_3	†
NH_4	15
PO_4	†
Na	†
$CaCO_3$	†
B	†
CN	0.5
Fe	†

*All concentrations estimated by SCS Engineers.
†Concentration not significant for this activity (i.e., high concentrations are tolerable).

TABLE 24. TYPICAL EFFLUENT QUALITY -- PAINT BOOTH WATER WALLS

Constituent	Concentration (mg/L)*
BOD_5	8,100
COD	13,600
Phenol	1.2
SS	2,800
TDS	†
O&G	280
Cl^-	†
NO_3	(28)
NH_4	(0.1)
PO_4	(3.0)
Na	†
$CaCO_3$	†
B	(0.1)
CN	(0.005)
Fe	3.2
Cr (Total)	13
Cu	(0.005)
MBAS	4,900

*Concentrations in parentheses estimated by SCS Engineers; other concentrations from Ref. 4.
†Concentrations dependent on source water quality.

Water quality requirements for plating rinse waters are shown in Table 22. Numerical quality limits for makeup waters for plating bath solutions cannot be standardized because there is such a wide variety of plating and finishing processes. Certain processes involve special water quality considerations. In plating baths, concentrations of iron, aluminum, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfide, sulfite, sulfate, flouride, chloride, silicate, copper, and lead have all been reported to cause difficulties under certain conditions.

Typical Effluent Quality

Effluent generated by metal plating and finishing operations is totally dependent on the types of processes involved. For this reason, no "typical" values are presented here.

In general, if reuse is not practiced internally, the waste can be expected to contain high concentrations of metal ions and cyanides, but will otherwise be of fairly high quality with only small quantities of BOD, phosphorus, oil and grease, and suspended solids contributed by the finishing operations.

Reuse Potential

Plating operations may offer limited reuse potential. High-quality secondary or tertiary effluent is a possible source of washdown water. It is doubtful, however, that a separate system providing reclaimed water only for washdown would be economically and practically feasible.

Some plating operations have utilized water from power plant scrubbers that are very high in SO_2 concentration. This water is used in the pretreatment operation to reduce hexavalent chrome to the trivalent form. Other water uses demand very high-quality water that would not be economically available in a reuse system.

Due to the high metals and/or cyanide content of the effluent from the plating shop, direct reuse in other activities is not generally practicable without pretreatment for cadmium removal and/or cyanide destruction prior to blending and further treatment. However, it appears possible to reuse the wastewater, after treatment, for many purposes.

Internal Recycling

There is excellent potential for reduction of the wastewater discharge volume and pollutant concentrations from plating shops. Process solution regeneration, chemical and metals recovery, water reuse and water savings can be accomplished by in-shop modifications of water flow patterns, metal recovery systems, good housekeeping, and water conservation. These modifications can be very economical and can significantly reduce water consumption, wastewater generation, and possible pollution control problems in

Reuse Potential

Painting facilities at Army posts appear to be good potential users of reclaimed water, since their wet walls and washdown activities do not demand high-quality water. Thus, highly disinfected secondary effluent could be used for these purposes.

The effluent from paint shops, however, is highly contaminated and has little or no value for potential reuse, unless significantly diluted, before further treatment.

Internal Recycling

Most paint shop water walls are recirculating, so the water is used over and over again until it is highly contaminated with paint. The batch is then dumped and replaced with fresh water.

The final wastewater is usually too small in volume and too highly contaminated to make on-site treatment and reuse feasible.

PHOTOGRAPHIC LABORATORIES

Description

Many Army posts provide photo processing facilities. These range from small shops running 8 hours per day, to large facilities operating 24 hours per day.

Flow

Generated volumes of wastewater range from 500 to 20,000 gal per day, depending upon the size and type of facility.

Tolerable Water Supply Quality

The water quality needed for use in photographic laboratories is listed in Table 25. The water quality limits are stringent, requiring high-quality water. Spots and stains on the product can be caused by excessive concentrations of Fe and Mn. Copper causes emulsions to fog and loss of strength of color developer (9).

Typical Effluent Quality

Table 26 provides typical effluent quality for discharges from photo processing operations. Photo lab effluents contain large quantities of chemical-reducing agents and high cyanide concentrations.

Reuse Potential

Because photo processing demands the use of very high-quality water, these facilities do not appear to be feasible recipients of reclaimed water.

TABLE 25. TOLERABLE WATER SUPPLY QUALITY -- PHOTOGRAPHIC LABORATORIES

Constituent	Concentration (mg/L)*
BOD_5	0.1
COD	1.0
Phenol	0.001
SS	1.0
TDS	700
O&G	0.2
Cl^-	200
NO_3	20
NH_4	0.1
PO_4	3.0
Na	100
$CaCO_3$	400
B	0.1
CN	0.01
Fe	0.3
Mn	0.5
Cu	0.5

*All concentrations estimated by SCS Engineers.

TABLE 26. TYPICAL EFFLUENT QUALITY -- PHOTOGRAPHIC LABORATORIES

Constituent	Concentration (mg/L)*
BOD_5	300
COD	500
Phenol	(0.001)
SS	225
TDS	2,900
O&G	(4.0)
Cl^-	†
NO_3	(8.8)
NH_4	(16)
PO_4	(9.3)
Na	†
$CaCO_3$	†
B	18
CN	(4.8)
Fe	2.0
Ag	0.5
pH	7.8

*Concentrations in parentheses are estimates by SCS Engineers, other data from Ref. 8, 11.
†Dependent on source water quality.

Wastewater volumes are generally too low to justify special cyanide destruction or other pretreatment facilities. The best chance for reuse is by blending and treatment of the photo lab waste at the STP or IWTP, with subsequent reuse of the combined effluent.

Internal Recycling

Many larger photographic shops, both military and commercial, practice in-plant pollutant reductions for silver and cyanides through recovery of bleaches and silver. These recovery systems have been shown to be cost-effective.

RECREATIONAL LAKES

Description

Man-made recreational lakes for picnicking, fishing, and boating can be filled with reclaimed water. In arid regions of the country, the artificial lakes can provide needed water-based recreation and wildlife habitat. These lakes can also double as fire protection reservoirs, and can serve as storage points in a reclaimed water system.

Flow

The lakes would be filled as needed, or when suitable quality effluent was available.

Tolerable Water Supply Quality

Table 27 summarizes tolerable water supply quality limits for limited body contact/recreational lakes. As shown, tertiary effluent with nutrient removal would be necessary to provide satisfactory quality.

Typical Effluent Quality

No discharge.

Reuse Potential

These lakes would be possible recipients of tertiary effluent, and would usually be available for limited body contact recreation only.

STEAM CLEANING

Description

Steam cleaning is practiced to remove grease and oil from vehicles and equipment prior to further maintenance. Steam cleaning operations are often located in wash rack areas, and are adjacent to buildings with vehicle and equipment maintenance and

TABLE 27. TOLERABLE WATER SUPPLY QUALITY -- RECREATIONAL LAKES (LIMITED BODY CONTACT)

Constituent	Concentration (mg/L)*
BOD_5	10
COD	60
Phenol	(0.01)
SS	10
TDS	(2,000)
O&G	(5.0)
Cl^-	300
NO_3	2.5
NH_4	0.1
PO_4	0.3
Na	250
$CaCO_3$	†
B	0.1
CN	(0.1)
Fe	(5.0)
pH (units)	5.0 - 9.0
Median coliform number	$\leq$ 2.2/100 mℓ
Temp (Max)	$86^{o}F$

*Concentrations in parentheses estimated by SCS Engineers. Other values come from Ref. 21.

†Concentration not significant for this activity.

repair functions. The steam cleaning equipment is usually outdoors on a dyked concrete pad, with wastewater running into a sewer or storm drain.

Flow

At Anniston Army Depot, a post with a major tank rebuilding function, there are a large number of steam cleaning operations located throughout the industrial area. Steam cleaning wastes are collected in a separate sewer system; thus, the total flow of steam cleaning wastes can be measured. Workday flow rates averaged approximately 40,000 gpd at Anniston. The average flow rate from a typical steam cleaning station, consisting of one steam nozzle and one rinse hose, was estimated at about 5 gpm.

Anniston has an intense steam cleaning program. Most bases will not use nearly this much water for steam cleaning.

Tolerable Water Supply Quality

See Vehicle Wash Racks.

Typical Effluent Quality

Various detergents and solvents are used in steam cleaning, and contribute phosphates and low levels of phenolics to the wastewater. The wastewater also has large concentrations of suspended solids, oil and grease, and may contain heavy metals. Table 28 summarizes typical effluent quality for steam cleaning wastes.

Reuse Potential

Steam cleaning effluent is a heavily contaminated industrial waste that requires extensive treatment before reuse. Direct cascade of steam cleaning effluent to another activity is, therefore, infeasible. Use of reclaimed wastewater for steam cleaning is possible if the water meets the tolerable water supply quality requirements. Disinfection is not necessary because the heat of the steam is sufficient to sterilize the water. It appears, therefore, that steam cleaning has cascade potential only as the recipient of high-grade tertiary effluent.

Internal Recycling

Internal recycling of steam cleaning waste is infeasible due to the heavy contamination of the effluent.

VEHICLE WASH RACKS

Description

All Army posts provide vehicle washing facilities, usually in the motor pool and engineering maintenance areas. The magni-

TABLE 28. TYPICAL EFFLUENT QUALITY -- STEAM CLEANING

Constituent	Concentration (mg/L)*
BOD_5	1,300
COD	2,800
Phenol	8.0
SS	1,000
TDS	--
O&G	245
Cl^-	--
NO_3	30
NH_4	0.1
PO_4	65
Na	70
$CaCO_3$	--
B	0.1
CN	<0.01
Fe	3.6
Cd	0.5
Cr^{+6}	0.3
Cu	0.2
Pb	0.6
Ni	<0.05
Zn	2.0
pH	9.7

*Based on Ref. 22.

tude of washing operations varies from post to post, depending upon the number of vehicles, type of vehicle (tank, half-track, 2-1/2-ton truck, jeep, etc.), road conditions, weather, and other factors.

For example, a wash rack cleaning tanks in muddy areas will use much greater volumes of wash water than a rack washing jeeps in a desert area.

In most cases, wash racks consist of 3/4-in to 1-1/2-in hose connections with spray nozzle attachments. Typically, detergent is sprayed onto the vehicle, dirty and oily areas are brushed manually, and the vehicle is spray rinsed. Wash waters are generally collected in floor drains, treated in an oil/water separator, and discharged to the sewer.

Depending on the number of vehicles being washed, bases may also have automated wash racks similar to commercial car wash operations.

Flow

Wastewater generation depends on many factors, as discussed above. Typical generation of wash rack wastewater is estimated as follows:

Vehicle	Gallons per Wash
Jeep/car	50-100
2-1/2-ton truck	500-1,000
Half-track	1,000-1,500
Tank	1,500-3,000

Tolerable Water Supply Quality

Tables 29 and 30 give two sets of water quality criteria for water supplied to wash racks. Table 29 applies when reclaimed sewage treatment plant effluent is being used. Table 30 applies when wash rack effluent is being internally recycled. The criteria for STP effluent are more stringent than those for internally recycled wastewater. This is because STP effluent contains human bacteria and viruses which can pose a threat to the health of workers in intimate contact with water sprays.

To reduce the numbers of human pathogens in sewage to acceptable levels, conventional primary and secondary treatment, tertiary treatment by filtration, and effective disinfection are required. Filtration lowers suspended solids to a level of 10 mg/L in a well-operated system. Suspended solids must be at this low level before effective disinfection can be achieved. In contrast, when internally recycled wastewater is supplied to wash

TABLE 29. TOLERABLE WATER SUPPLY QUALITY -- VEHICLE WASH RACKS USING SEWAGE TREATMENT PLANT EFFLUENT

Constituent	Concentration (mg/L)*
BOD_5	10
COD	25
Phenol	2.0
SS	10
TDS	2,000
O&G	5.0
Cl^-	600
NO_3	†
NH_4	5.0
PO_4	†
Na	600
$CaCO_3$	500
B	†
CN	0.5
Fe	40
Pb	1.0
Median coliform number	≤2.2/100 mℓ

*All concentrations estimated by SCS Engineers.
†Concentration not significant for this activity.

TABLE 30. TOLERABLE WATER SUPPLY QUALITY -- VEHICLE WASH RACKS USING INTERNALLY RECYCLED WATER

Constituent	Concentration (mg/L)*
BOD_5	20
COD	100
Phenol	3.0
SS	60
TDS	2,000
O&G	5.0
Cl^-	600
NO_3	†
NH_4	15
PO_4	†
Na	600
$CaCO_3$	500
B	†
CN	0.5
Fe	40

*All concentrations estimated by SCS Engineers.
†Concentration not significant for this activity.

racks, the level of suspended solids can be higher, the only consideration being the possible loss of washing quality at levels higher than 60 mg/L.

Typical Effluent Quality

Table 31 summarizes typical effluent quality from vehicle washing operations. As shown, the waste is high in SS, COD, and O&G. If solvents and detergents are heavily used, the waste will also contain significant amounts of MBAS, phosphates, and perhaps phenol.

Reuse Potential

Vehicle washing appears to have potential as a recipient of high-grade tertiary sewage treatment effluent. In most cases, the cost of tertiary treatment is not economically justifiable solely for the purpose of supplying reclaimed water to wash racks. If a highly disinfected tertiary effluent is required for other purposes, then wash racks are potential users.

Internal Recycling

Wash rack wastewater can be used for internal recycling if the quality of the effluent meets the general criteria set in Table 30. Treatment for internal recycling usually involves settling, grease and oil separation, and filtration. To remove heavy suspended solids and free oil, water from the wash racks is discharged to settling basins for a detention time of at least 2 hours. Sludge is pumped off the bottom to holding tanks or beds, while the free oils are removed by floating oil skimmers. Water from the settling basins is then pumped over sand filters to remove suspended solids remaining in the wastewater.

The U.S. Army Construction Engineering Research Laboratory at Champaign, Illinois, is studying the design, construction, and operation of centralized facilities for tactical vehicle washing (2,3). Treatment of the wastewater by settling, skimming, and intermittent sand filtration has been investigated on a pilot scale. It appears that the effluent would be of high enough quality to be recycled.

Centralization of wash rack facilities increases the feasibility of reuse or recycling because, at a single, large facility, enough water could be used to justify costs for piping, storage, and treatment. This concept is most applicable to Army facilities washing large numbers of tactical vehicles.

The Army has also evaluated various membrane processes for the internal treatment and recycling of wash rack water. Under normal circumstances, these processes prove too expensive for typical, uncentralized washing operations that do not use enough water to justify the cost of treatment.

TABLE 31. TYPICAL EFFLUENT QUALITY -- VEHICLE WASH RACKS

Constituent	Concentration (mg/L)*
BOD_5	60
COD	900
Phenol	(0.01)
SS	2,000
TDS	†
O&G	60
Alkalinity ($CaCO_3$)	115
Cl^-	†
NO_3	(3.3)
NH_4	(0.01)
P (Total)	33
PO_4	(12)
Na	†
$CaCO_3$	†
B	(0.01)
CN	(0.005)
Fe	4.7
Zn	2.9
Pb	2.5
Mg	15
Ca	31

*Concentrations in parentheses estimated by SCS Engineers; other data from Ref. 3,8.

†Concentrations are strongly dependent on source water quality.

Wash rack wastewater recycling has been practiced at Fort Hood, Texas, for several years. The wastewater is ponded, and is reused for "rough washing." Tactical vehicles are sometimes "rough washed" immediately after they return from maneuvers and "fine cleaned" later. A new vehicle washing facility with wastewater recycling has been completed at Fort Riley, Kansas. A centralized wash rack facility is under design at Fort Drum. Others are being considered at Fort Knox and Fort Carson.

IV

EVALUATION MODEL DESCRIPTION

This section describes the three tiers of the Subpotable Wastewater Reuse Evaluation Model. This model is a tool to be used by the Army in assessing the potential for reuse at all their posts and in aiding development of optimal reuse systems.

The tiered or phased approach allows for the most efficient use of time and monies. Admittedly, many posts will not be good candidates for reuse. The first tier of the model provides a fast, effective means of eliminating these bases from further consideration. Tier II provides a tool for evaluating the economic feasibility of reuse, and a means for further narrowing the group of remaining posts to those with excellent reuse potential. At this point, Tier III is utilized to aid in the selection of the best reuse systems or networks for each post. Tier III leads to preliminary engineering designs for the final reuse system.

Each tier will be discussed in order, and the following topics will be covered:

- Purpose
- Development
- Required data and experience
- How to use the model
- Discussion of model
- Model applications (Tier I only).

Appendix A presents the actual model.

TIER I - WASTEWATER REUSE POTENTIAL EVALUATION MODEL

Purpose

The purpose of the Tier I Evaluation Model is to provide an efficient method for quantifying the potential for wastewater reuse at fixed Army facilities. The model has been designed so that a knowledgeable person can complete the Tier I analysis in approximately one day, without having to personally visit the installation.

By evaluating the results of Tier I, the Army should be able to eliminate bases with little potential for reuse, and concentrate on the Tier II and Tier III efforts on those bases that show good potential.

Development

The Tier I model was developed using a paired comparison weighing approach.

First, five general categories or criteria were developed as reflective of reuse potential at an Army base. These criteria are: climate, activities, water supply, wastewater, and institutional aspects. These major criteria were rank ordered as to importance for wastewater reuse as follows:

- Water supply
- Wastewater
- Activities
- Institutional aspects
- Climate.

In order to weigh the importance of each criterion, a paired comparison procedure was used. Assigning a value of 100 to the first ranked criterion, each following criterion was ranked (by Delphi technique) as a percentage of importance compared to the criterion immediately above. The result was as follows:

Criterion	Weight as Compared to Criterion Immediately Above	Weight as Percentage of Whole
Water Supply	100	25
Wastewater	100	25
Activities	80	20
Institutional Aspects	90	18
Climate	60	12

Thus for Tier I, the water supply and wastewater categories each carry 25 percent of the total weight, while base activities are slightly less important at 20 percent, followed by institutional aspects at 18 percent and climate at 12 percent.

In order to reflect these weightings, the optimum score in each of the five categories of the Tier I model represents the aforementioned percentages of the total possible score.

It was deemed unnessary to carry the paired comparison approach to the next level of criteria under each of the five major categories; rather, a Delphi approach was used to arrive at the point values for each question. Each member of the project team worked independently in assigning point values to each question. These values were averaged and then adjusted uniformly so that the total possible point score for the category would be correct.

Required Data and Experience

Completion of Tier I requires a sound general knowledge of five major information areas of the post: water supply, wastewater treatment/disposal, activities, institutional aspects of the water and wastewater systems, and climate. The evaluator responsible for completing Tier I need not be a sanitary engineer; however, they should be familiar with Army posts, should be completely briefed on the purpose and use of the Tier I model, and should have enough technical background to adequately interact in discussions of water supply systems, wastewater treatment, Army activities, etc.

Most importantly, the evaluator must locate a key person or persons at each post who has or knows where to obtain the type of information needed for Tier I. This person will most likely be working in the Facilities Engineering office. The model can be quickly and efficiently completed if these key people can be located.

How to Use the Model

Tier I is very straightforward. The evaluator merely answers each question based on data available in base records, or by interviews with key base personnel. The total score will fall into one of the four categories for reuse potential delineated at the end. Based on the result, the base will either be dropped or the evaluator will continue on to Tier II.

Discussion of Tier I Model

This section provides a discussion of the reasoning behind the selection of individual questions and their importance for each of the five categories. The complete Tier I questionnaire can be found in Appendix A.

Water Supply--

A key to wastewater reuse potential is the availability and cost of the base water supply, both now and in the future. Water shortages, potential water supply problems, and large water usage are all factors that make reuse look more attractive.

Question 1. Is the base water supply available from a reliable source for the next 20 years?

Remarks: A negative response signals possible long-range supply problems, a plus for reuse.

Question 2. Is there possible significant depletion of the water supply within 10 years?

Remarks: A negative response means future planning and possible design of new water supply facilities - a good time to evaluate reuse.

Question 3. Is there an anticipated problem with the water supply within 5 years?

Remarks: Negative response: High rating for reuse as evaluation and planning for new or additional water supplies should include reuse possibilities.

Question 4. What is the present cost of water procurement and treatment per 1,000 gal?

Remarks: High water costs are a driving force for reuse as the economics of reuse become more attractive.

Question 5. Is there a foreseeable event that could markedly increase water costs in the next 10 years?

Remarks: Although costs may be reasonable now, many areas are realizing increased costs as water sources are depleted and quality degrades. Future cost increases benefit reuse economics.

Question 6. Is expansion or upgrading of the water supply/treatment systems planned in the next 10 years?

Remarks: Reuse can provide savings in reduced plant capacity. Planning should include reuse feasibility.

Question 7. What volume of water is used on the average in MGD?

Remarks: Bases using large volumes of water realize economies of scale when considering the cost of reuse facilities. High usage may also reflect extensive irrigation and/or large industrial users; both are positive for reuse.

Question 8. What is the TDS (mg/L) of the base water supply?

Remarks: High TDS water is less attractive for reuse because of the low salt tolerance of some vegetation and the reduced recycle potential in cooling systems. Domestic use increases TDS by 300 mg/L, thereby increasing reuse problems where the water supply is already high in TDS.

Wastewater--

Wastewater management is an important consideration for reuse: treatment facilities, effluent quality, discharge requirements, costs, and volumes are all important factors. In general, bases with large, expensive treatment facilities discharging high-quality effluent have good reuse potential; this is also true of bases at the other extreme with outdated or overloaded treatment facilities that are unable to meet discharge requirements.

Question 9. Does the base treat wastewater for direct discharge to surface water or land?

Remarks: Direct discharging bases are given positive reuse ratings because of the problems associated with meeting increasingly stringent discharge requirements. Reuse is one answer for reducing plant loadings, or for eliminating discharges altogether.

Questions 10 to 13 for Base STP Only

Question 10. Does the treatment plant presently meet discharge requirements?

Remarks: A negative response indicates a wastewater management problem for which reuse may be part of the solution.

Question 11. Will additional treatment facilities be required within the next 5 years?

Remarks: A positive response indicates planning, design, and construction of new facilities. Reuse could have positive impact, or could conceivably alleviate the problem so that new facilities would not be necessary.

Question 12. What quality is the plant effluent in terms of BOD (mg/L)?

Remarks: Good quality effluent is a bonus for reuse in that little extra treatment is required for reuse and, therefore, the economics look more advantageous.

Question 13. What percentage of design capacity is in use?

Remarks: As plants near design capacity, decisions on expansion/reuse have to be made. Problems with overloading may be alleviated by reuse.

Questions 14 to 16 for Base IWTP Only

Question 14. Does the treatment plant presently meet discharge requirements?

Remarks: (Same as 10.)

Question 15. What quality is the plant effluent in terms of COD (mg/L)?

Remarks: (Same as 12.)

Question 16. Are discharge limits set for specific contaminants (i.e., heavy metals, CN, nutrients)?

Remarks: Industrial waste treatment plants with specific contaminant limits are likely to have a higher quality effluent (better for reuse). They may also have problems meeting these discharge standards, in which case reuse may be of assistance.

Question 17. What total quantity of wastewater, treated and untreated, is discharged from the base in MGD?

Remarks: Economies of scale favor reuse at bases with large wastewater volumes.

Question 18. If the base discharges to a municipal or regional sewer system, what is the discharge fee per MG?

Remarks: High discharge fees have a positive effect on reuse economics.

Question 19. Are future changes likely that would markedly increase the discharge fee?

Remarks: Again, future increases in discharge fees can have a positive impact on current reuse planning.

Activities--

In order to have a successful reuse program, Army bases must have sinks, i.e., activities where the reclaimed water can be used. Without sinks, reuse is impossible. In addition, it is advantageous for a base to have large industrial activities that either generate large volumes of reclaimable wastewater or that can use reclaimed water as a supply.

Question 20. Does the base have a golf course?

Remarks: Golf courses are the best sink on most bases, as reclaimed water can be used for irrigation. This can be a very high-volume use, depending on the climate.

Question 21. Is the golf course irrigated?

Remarks: If the course is already irrigated, then reclaimed water can be substituted and the existing sprinkler system utilized. However, even if the course is not currently irrigated, if reclaimed water is available, an irrigation system can be constructed.

Question 22. How many acres of landscape and athletic fields could be irrigated if reclaimed water were available?

Remarks: Again, irrigation of landscape and athletic fields is a good sink for reclaimed water.

Question 23. How many large industrial cooling towers does the base have?

Remarks: Cooling tower makeup is another good use for reclaimed water.

Question 24. If the base has a plating shop, how much wastewater does the shop discharge in 1,000 gal/day?

Remarks: Large plating shops prove the potential for water savings by internal treatment/recycle, and usually discharge large volumes of wastewater that, when properly treated, provide a good source of reclaimed water.

Questions 25 through 34.

Remarks: All these questions refer to the presence or absence of key activities on the base that have potential as sinks for the use of reclaimed water. The more important activities are given more value.

Question 35. Does the base have a large pesticide management program?

Remarks: Pesticide disposal can generate highly contaminated wastewaters. Bases with a pesticide management program are rated favorable for reuse, as these toxic contaminants must be removed at the source before they can enter the wastewater system.

Question 36. Does the base have any other activities using more than 25,000 gpd that we have not included?

Remarks: We may have omitted something. Depending on the significance of the omission, the evaluator assigns a point value.

Institutional Aspects--

Experience has shown that institutional and legal aspects of reuse programs can be extremely important at military bases. In some instances, legal constraints or negative attitudes towards reuse have stopped reuse programs that were technically feasible and economically justified.

Question 37. Is the base free of any long-term purchase agreements that would prohibit the base from cutting back on water usage?

Remarks: Constraints on the ability to reduce water usage are obviously detrimental to reuse programs.

Question 38. Is the base free of any water laws (i.e., Doctrine of Prior Appropriation) or commitments to regional wastewater systems that would prohibit a reduction in volume of effluent discharged?

Remarks: Constraints on the ability to reduce wastewater discharge volumes are detrimental to reuse programs.

Question 39. Is wastewater reuse occurring now or being planned in surrounding communities?

Remarks: Reuse in surrounding areas portends of local pressures and a favorable legal/institutional climate for reuse.

Question 40. What percentage of the total wastewater generated on-base is currently being reused?

Remarks: Bases already reusing a portion of their wastewater are obvious candidates for a more comprehensive reuse plan.

Question 41. Is there a potential large civilian water user near the base (i.e., golf course, power plant, agriculture)?

Remarks: Large civilian water users near the base can offer a sink for reclaimed water if the quality is sufficient and the economics of transport are feasible.

Question 42. Are key base personnel interested in using reclaimed water?

Remarks: The attitudes of key personnel towards wastewater reuse is a prime factor in the success of a program.

Climate--

A last major area of interest is climate. Because of the value of irrigation as a major reuse application, bases located in arid and semi-arid areas have an advantage over bases located in areas with high rainfall. Although it is not always the case, bases located in dry areas tend to have more serious water supply problems than those in more temperate zones.

Question 43. What is the average yearly rainfall on the base in inches/year?

Remarks: Areas with low rainfall are rated as more positive for reuse.

Question 44. What is the average yearly pan evaporation on the base in inches/year?

Remarks: Areas with high evaporative loss are apt to have a higher demand for reclaimed water.

The final page of the Tier I model delineates four categories of final scores. These are as follows:

0 to 54 points:	Poor potential, no further evaluation
55 to 74 points:	Marginal potential, evaluator's decision on whether to pursue Tier II
75 to 100 points:	Good potential, proceed to Tier II
Over 100 points:	Excellent potential, proceed to Tier II and note possibility of Tier III.

Model Applications

The Tier I evaluation model was tested at three Army bases: Fort Ord, Fort Jackson, and Anniston Army Depot. Table 32 shows the results of these trial applications.

As shown, Fort Ord ranked in the highest reuse category, and is a good example of a base that has excellent reuse potential. It ranked very high in all categories but Wastewater.

Fort Jackson scored at the top of the marginal potential category with 72 points. Fort Jackson scored well in the Water Supply and Activity categories, but very low in the Wastewater and Institutional categories, and should be evaluated under the Tier II model.

Anniston Army Depot ranked in the marginal reuse potential category. Anniston has many large industrial activities and wastewater management problems that scored well for reuse. However, the base has no water supply problems, and rated low in Institutional aspects and Climate.

At the time of this report completion, the Army is planning to run Tiers II and III at two Army posts during the summer of 1979. The bases tentatively selected are: Ft. Bliss, Tobby Hannah Army Depot.

TABLE 32. TRIAL APPLICATIONS OF THE TIER I EVALUATION MODEL

Category	Points		
	Fort Ord	Fort Jackson	Anniston Army Depot
I. Water Supply			
1	4	4	0
2	6	0	0
3	9	9	0
4	6	4	4
5	5	5	0
6	3	3	0
7	5	5	2
8	2	4	2
Subtotal	40	34	8
II. Wastewater			
9	7	0	7
10	0	NA	6
11	0	NA	4
12	2	NA	0
13	0	NA	2
14	NA	NA	6
15	NA	NA	0
16	NA	NA	3
17	NA	3	2
18	NA	3	NA
19	NA	0	NA
Subtotal	9	6	30
III. Activities			
20	4	4	0
21	3	3	NA
22	4	4	4
23	0	2	1
24	0	0	4
25	0	0	1
26	2	2	2
27	1	0	1
28	0	0	0
29	2	2	2
30	0	0	0
31	3	0	0
32	1	1	1

TABLE 32 (continued)

Category	Points		
	Fort Ord	Fort Jackson	Anniston Army Depot
III. Activities			
33	0	0	0
34	0	2	2
35	0	0	0
36	0	0	0
Subtotal	20	19	18
IV. Institutional Aspects			
37	4	4	4
38	0	4	4
39	6	0	0
40	0	0	4
41	4	0	0
42	8	0	0
Subtotal	22	8	8
V. Climate			
43	7	0	0
44	4	4	4
Subtotal	11	4	4
TOTAL POINTS	102	72	72

TIER II - WASTEWATER REUSE POTENTIAL EVALUATION MODEL

Purpose

The purpose of the Tier II Evaluation Model is to provide an efficient method for the Army to assess the reuse potential of those bases that scored well in Tier I. Tier II is critical: the bases that show potential through Tier II are destined for detailed evaluation and conceptual system design, at significant time and expense, under Tier III.

Tier II, thus, is the intermediate process between the general Tier I and the detailed Tier III. Tier II will cost the Army a few thousand dollars per base.

Development

The Tier II model is a re-creation of engineering procedures used by SCS Engineers in previous water reuse evaluations of military facilities. To the maximum extent possible, the model leads the reviewer through a step-by-step approach. However, the more sophisticated nature of Tier II requires engineering judgement.

Required Data and Experience

It is estimated that the Tier II will require 10 to 15 man-days per base. The following general tasks will be involved:

1. Base investigation

   - Review of existing water- and wastewater-related records

   - Interviews with key personnel

     - Base maps
     - Descriptions of activities
     - Existing treatment description, performance, and cost
     - Costs for water procurement and treatment
     - Future plans and developments

   - Possible minor activity sampling (bucket and stop-watch).

2. Implementation of Tier II evaluation model

3. Decision as to whether or not to proceed to Tier III effort.

Tier II requires more detailed data than Tier I. As mentioned above, key personnel must be interviewed and base records reviewed for pertinent information. A short summary of the data needed for Tier II is as follows:

- Activities - daily/monthly water usage and wastewater generation, seasonal usage patterns
- Spatial relationships - base map and exact/location of all activities
- Costs for water supply and wastewater treatment/disposal
- Type of wastewater treatment and plant performance
- Future plans for expansion or upgrading of water and/or wastewater systems.

Tier II requires engineering judgement. We recommend that the evaluator be an environmental engineer with experience in Army post activities, and with general knowledge of wastewater treatment units, water piping systems, and the concepts of water reclamation and reuse. The model contains most of the detailed cost and performance information required; however, this data must be utilized by a knowledgeable engineer to obtain optimum results.

How to Use the Model

The Tier II model is straightforward: the evaluator follows instructions, provides data, and makes decisions as required. The model will lead to development of simplified reuse schemes for the base. These, in turn, will be evaluated economically in the last section of Tier II to allow comparison of the feasibility of reuse.

Discussion of Tier II Model

Tier II is divided into four sections. Each section builds on the data generated in the previous section, and all lead to a final economic analysis of reuse alternatives. The four sections of Tier II are:

- Activities
- Spatial relationships
- Conceptual reuse systems
- Economics.

The Activities Section leads to a complete listing of all base activities to be considered for inclusion in the reuse systems, while the Spatial Relationships Section aids in locating these activities and eliminating those that are too far removed from the main reuse system to be feasible. The heart of the Tier II model is the third section. Here, conceptual reuse networks

are laid out for eventual cost comparison, and treatment requirements are assessed, including upgrading of existing facilities. Finally, the completed reuse systems are subjected to a simplified cost analysis.

Appendix A contains a complete presentation of the Tier II model. The model is complete with all operational instructions and descriptions of required supportive data.

TIER III - WASTEWATER REUSE POTENTIAL EVALUATION MODEL

Purpose

The purpose of the Tier III evaluation model is to assist the Army in selecting the best water reuse systems at posts with high reuse potential. Tier III is the final phase of the model and leads to preliminary engineering designs of reuse networks.

Tier III is not to be used for final design and costing purposes, but rather as a tool to efficiently compare the overall estimated costs of selected reuse schemes.

Development

The Tier III model is based on previous work performed by SCS Engineers for the Air Force[23]. Tier III centers on a computer model that is used to simulate reuse schemes at each post that has qualified after Tier II.

Section V of this report summarizes the modifications that were made to the original computer program so that it would now accurately reflect Army water management options. Section V also summarizes the results of test runs of the computer model at a hypothetical Army base called "OVERLORD."

Required Data and Experience

Tier III is a detailed post survey requiring up to 3 man-months of effort and a cost of approximately $43,000. Note, however, that approximately 50 percent of these costs are for sampling and analysis which, if done in-house by the Army, could greatly reduce the Tier III cost. A general breakdown of these costs is as follows:

• Labor and Overhead	$15,000
• Sampling equipment and sample analysis	21,000
• Transportation and Per Diem	3,000
• Phone, Reproduction, and other Direct Costs	1,000
• Profit (if performed by private contractor)	3,000
TOTAL	$43,000

Tier III should be used only at highly qualified bases, namely those that showed positive results on Tiers I and II.

The following general tasks are involved:

1. In-depth base visit (20-30 man-days)

- Interviews with base personnel to expand on Tier II data

- Composite and grab sampling of all activities without good existing data. This, along with interviews, should yield complete activity descriptions.

- Survey of the base for location of possible new treatment, storage, or pumping facilities, and best location for reclaimed water pipelines.

2. Completion of all input data for the computer program (Phase I)

3. Run Phase I of computer program

4. Completion of conceptual networks and other Phase II computer program input

5. Run Phase II of computer program

6. Complete Tier III evaluation and make conclusions and recommendations.

Tier III requires accurate data on all important reuse activities (previously identified in Tier II) for each post. This involves information on: water usage, wastewater generation and characteristics, and tolerable water qualities if reclaimed water is to be used. The model is set up to accept flow information on either a daily or a monthly basis. It is usually necessary to sample with automatic composite samplers or at least a thorough grab sample program to get this data for all activities required. Past work has shown that most posts will include about 10-15 activities, and will incorporate about 10-15 wastewater characteristics (SS, BOD, etc.) in the data base.

Tier III does not require the services of a computer programmer, although general knowledge of Fortran and data entry procedures is always useful. Tier III does require an environmental engineer to evaluate interim computer output and to make decisions as to appropriate reuse/networks for testing. The engineer must also evaluate final cost figures, make adjustments for existing equipment, and perform other engineering judgements. The model is not the answer, but a tool to aid the engineer in arriving at the answer.

At the time of this writing, the Tier III portion of the model will be implemented by the Army Construction Engineering Research Laboratory, Champaign, Illinois (CERL). The CERL computer will be programmed to run the Tier III reuse model, with assistance from SCS Engineers if necessary.

All Tier III documentation can be found in Volume II of this report. Included in Volume II is the:

- Users Manual - containing a complete description and layout for the Tier III computer program data, including addendum sheets for the new modifications made under this contract
- Program Copy - a copy of the reuse computer program.

In addition, the program source deck has been provided to CERL in Champaign, Illinois.

How to Use the Model

Use of the computer model is straightforward. It requires input from the evaluator in two areas. Initially, activity data as well as treatment efficiencies must be provided for all treatment processes to be considered. After the first phase of the program is complete, the evaluator must input various reuse systems that he wishes to test. The computer then performs the calculations.

All required information for data entry and operating of the model is contained in the "Users Manual." It provides forms and samples for all required information.

Obviously, the evaluator must have access to a computer that can accept the language, and that has sufficient memory storage capability. The program is written in American Standard Fortran IV, and was originally tested on a CDC 6600 computer. The program is large and requires approximately 260,000 bytes of computer core.

Discussion of Tier III Model

The purpose of this section is to explain briefly:

1. How the program works.
2. What quantitative input data is required from base personnel.
3. What output can be anticipated.
4. What decisions will have to be made by the base engineer.

Comprehensive step-by-step instructions for completing all required input forms and data are supplied in the "Users Manual."

The reader is cautioned that he should not expect to thoroughly understand the computer program by a first reading of this section. Several thousand man-hours of effort were expended to develop this software, and the average engineer will have to thoroughly review the Users Manual before undertaking work with

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SUBPOTABLE WATER REUSE AT ARMY FIXED INSTALLATIONS: A SYSTEMS A--ETC(U)
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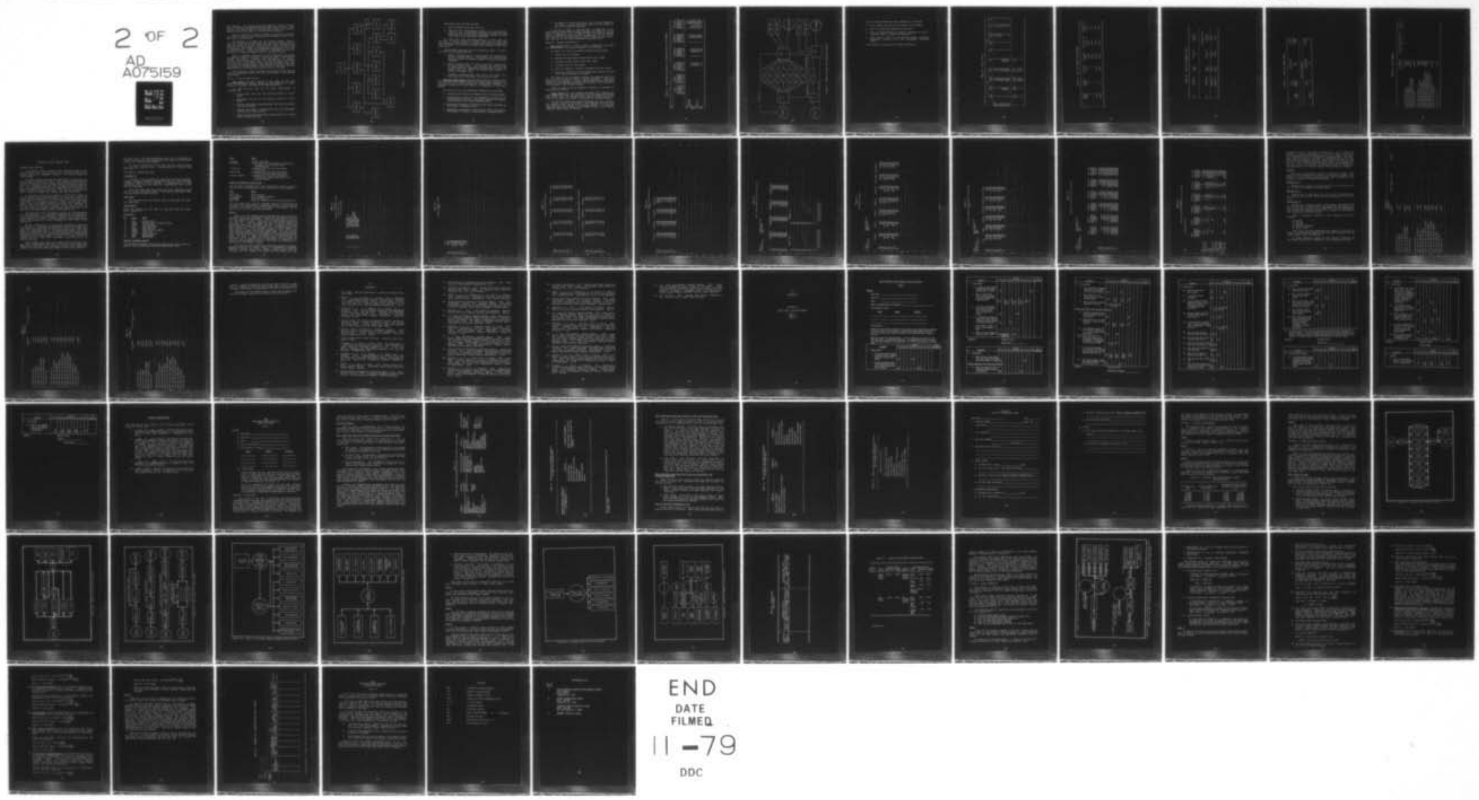

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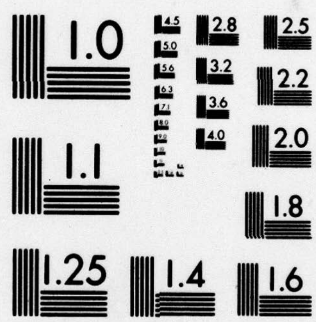

MICROCOPY RESOLUTION TEST CHART
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the computer. The rewards are great, however, because the computer can analyze many potential alternate reuse systems. Thus, results which would take an engineer many months to accomplish manually, can be obtained in a few minutes by computer.

Figure 1 shows the structure diagram for the entire program. The figure delineates the interconnections between the main program and all subroutines.

The software is divided into two separate phases. Phase I (Activity Description) assimilates activity data supplied by the base and prints out several forms for each activity showing flow patterns, effluent quality characteristics after various levels of treatment, the effects of recommended pretreatment units, and cascade potential. Output from Phase I is intended to assist the engineer in selecting feasible activity cascade networks.

Phase II (Network Feasibility) quickly evaluates any number of potential networks selected. Output provides a comprehensive network description, including the requirements for piping, pumping, and storage facilities, the required removal efficiencies, the type of treatment chains, and the estimated total cost of the entire cascade system. Continued modification of the most cost-effective cascade networks should lead to selecting the most comprehensive, cost-effective reuse system for the base.

The following sections delineate in more detail the required input and generated output data for both phases of the cascade reuse model.

Phase I - Activity Description--

Base input--The major portion of the input to the first phase of the model involves gathering and presenting in proper format all necessary information on base activities.

For each activity, and for all water constituents of interest; the

1. Source water flow into the activity (hourly if available).

2. Wastewater flow out of the activity (hourly if available).

3. Average constituent concentrations for the source water into the activity.

4. Average constituent concentrations for the wastewater flowing out of the activity.

5. Maximum acceptable contaminate concentrations for source water into the activity.

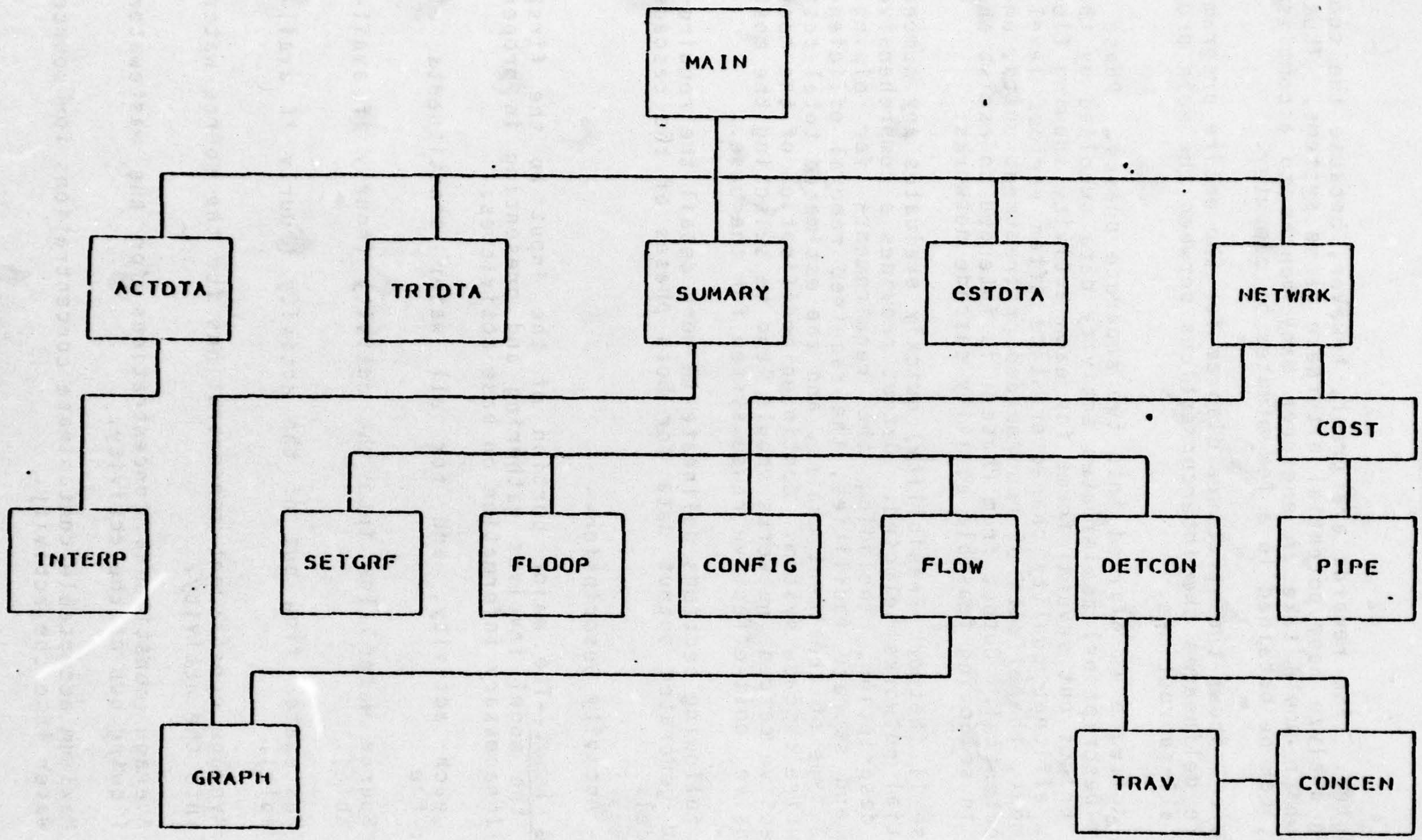


Figure 1. Program Structure Diagram

Additional data required include:

1. Base freshwater source(s) quality.

2. Required final discharge(s) quality, i.e., the restrictions, if any, on the final discharge or discharges from the base to a surface water, municipal system, or other final receiver of the waste discharge.

For Army posts that fluctuate greatly in troop level and activity, it may be prudent to gather individual activity data for periods of both high and low mobilization and/or production. Then the model can be used to assess reuse potential under both conditions.

The following data may also be included as input if different from the preprogrammed data:

1. Removal efficiencies of various pollutant constituents by the treatment chains. For example, the engineer may choose to show a 90 percent removal of BOD_5 by secondary treatment.

2. Removal efficiencies of various pollutant constituents by pretreatment units. For example, the engineer may stipulate chemical coagulation pretreatment on some unit process that will achieve 50 percent BOD_5 removal, 70 percent SS removal, etc.

3. Threshold concentrations over which the model will assign special pretreatment units at activities.

<u>Computer model output</u>--Output from the Phase I program fully describes the activities and possible cascade flows from activity to activity with varying degrees of intervening treatment. A thorough discussion of this output is presented in the Users Manual.

For each activity, the following information is provided:

1. Cumulative and hourly or monthly flows including graphs.

2. Constituents in and out and degradation through use as average concentrations in mg/L and loadings in lbs/day, and tolerable source water concentrations.

3. Wastewater contaminant concentrations after treatment by each regular treatment chain.

4. Wastewater contaminant concentrations after appropriate pretreatment followed by each regular treatment chain.

5. A summary of the suitability of the activity wastewater for reuse in other activities after various levels of special and regular treatment.

At the end of Phase I, previous data is summarized in one table showing acceptable cascades between activities at various levels of treatment. This is shown in Table 33, where X's denote totally acceptable quality for the cascade, and 1's and 2's denote that one or two constituents, respectively, are not acceptable, whereas all the other parameters are permissible.

Phase II - Network Feasibility--

Base input--Phase II input involves appropriate cost data and representation of cascade networks to be analyzed.

Cost data that must be provided includes the following:

1. Annual rate of interest.
2. Engineering News Record Construction Cost Index.
3. Engineering News Record Labor Cost Index.
4. Estimated life of the system.
5. Costs of regular or special treatment units or chains.
6. Cost per 1,000 gal for each source water supply and each final waste discharge to disposal.

With the aid of the Phase I output, the engineer should be able to develop several feasible cascade networks. These networks must be presented in proper format along with all estimated lengths of pipe between activities and treatment facilities which are included in the cascade network.

Figure 2 shows a typical schematic diagram of a network for March AFB, California.

Model output--For each network provided, this cascade program summarizes flows and concentrations throughout the system, and finally lists all related costs. Again, a detailed discussion of all Phase II printout is presented in the Users Manual.

At each BTS (Blending-Treatment-Storage) unit in a network, the program summarizes and graphs: flows through the BTS, storage required, and makeup or discharge needed. In addition, required constituent removals are listed as well as all concentrations into and out of the BTS.

TABLE 33. ACCEPTABLE CASCADES AT VARIOUS LEVELS OF TREATMENT

Base:	NONE	PRIMARY	SECONDARY	FILTRATION	CARBON ADS	REV. OSMOS
	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH	AHBOPAGVOGAH
	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO	/OOFHHEWFOHO
	AUQFOHNRFLIS	AJQFOHNRFLIS	AUQFOHNRFLIS	AUQFOHNRFLIS	AUQFOHNRFLIS	AUQFOHNRFLIS
	WS T I IFRP	WS T I IFRP	WS T I IFRP	WS T I IFRP	WS T I IFRP	WS T I IFRP
	RE O R R R	RE O R R R	RE O R R R	RE O R R R	RE O R R R	RE O R R R
A/AWR						1 21222
...OIL+GREASE					2 2	1 11111
...CHEM COAG					2 12111	X XXXXX
HOUSE			X XXX	X XXXXX	X XXXXX	X222 2XXXXX2
BOQ			X XXX	X XXXXX	X XXXXX	X222 2XXXXX2
OFF			X XXX	X XXXXX	X XXXXX	X222 2XXXXX2
PHOTO			2 22222	X 1X111	X 1X111	X222 21X1112
...METAL REM			2 22222	X 1X111	X 1X111	X11111XXXXX1
AHH			X XXX	X XXXXX	X XXXXX	X222 2XXXXX2
VWR				1 111	X XXXXX	X22222XXXXX2
HOSP			X XXX	X XXXXX	X XXXXX	X222 2XXXXX2

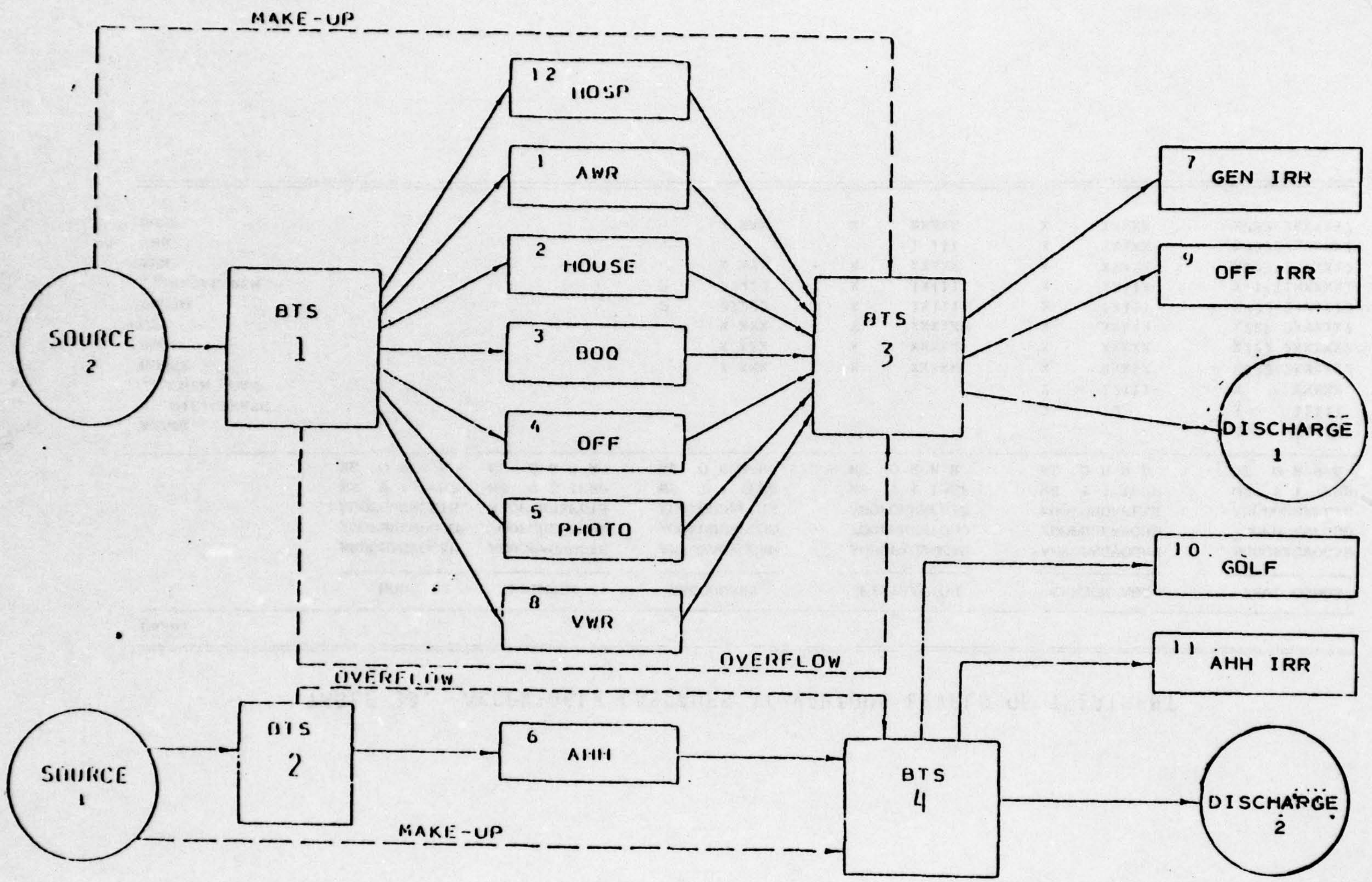


Figure 2. Sample Cascade Reuse Network Diagram

Costs for each network are then summarized, including:

1. Size, length, and cost of all pipes in the network.

2. Cost of storage and pumping for each BTS.

3. Costs and descriptions of special treatment at activities and regular treatment at each BTS.

4. Total yearly costs for the cascade system, including freshwater purchase and final wastewater discharge costs.

(See Tables 34 through 38 for sample printouts.)

TABLE 34. COST OF PIPE

	IN					OUT				
	SIZE (IN.)	LENGTH (FT.)	MAX FLOW (GPH)	COST/FT ($)	COST ($)	SIZE (IN.)	LENGTH (FT.)	MAX FLOW (GPH)	COST/FT ($)	COST ($)
A/AWR	2.	0.	1000.	4.00	0.	4.	0.	800.	8.00	0.
HOUSE	3.	0.	5000.	6.00	0.	4.	0.	5000.	8.00	0.
BOQ	1.	0.	500.	2.00	0.	4.	0.	500.	8.00	0.
OFF	6.	0.	15000.	12.00	0.	6.	0.	15000.	12.00	0.
PHOTO	2.	0.	2000.	4.00	0.	4.	0.	2000.	8.00	0.
AHH	6.	0.	18000.	12.00	0.	6.	0.	18000.	12.00	0.
GENIR	6.	3200.	14600.	12.00	38400.	0.	0.	0.	0.00	0.
VWR	1.	7500.	250.	2.00	15000.	4.	0.	225.	8.00	0.
OFFIR	4.	4000.	10500.	8.00	32000.	0.	0.	0.	0.00	0.
GOLF	10.	3600.	60000.	20.00	72000.	0.	0.	0.	0.00	0.
AHIRR	8.	7000.	28000.	16.00	112000.	0.	0.	0.	0.00	0.
HOSP	2.	0.	2500.	4.00	0.	4.	0.	2500.	8.00	0.

BTS	SIZE (IN.)	LENGTH (FT.)	MAX FLOW (GPH)	COST/FT ($)	COST ($)
1	6.	0.	26000.	12.00	0.
2	6.	0.	18000.	12.00	0.
3	6.	0.	24300.	12.00	0.
4	10.	0.	59000.	20.00	0.

TABLE 35. COST OF PUMPING AND STORAGE

BTS	STORAGE (GAL)	DIAMETER (FT)	STO. COST ($)	MAX. FLOW (GPH)	PUMP CAP COST ($)	PUMP O&M COST ($/YR)
1	0.	0.	0.	26000.	26899.	1096.
2	0.	0.	0.	18000.	22547.	843.
3	1282.	4.	1356.	25350.	26574.	1075.
4	78398.	33.	16500.	65000.	41759.	2329.

TABLE 36. SPECIAL TREATMENT COSTS

ACT	TREATMENT	FLOW (GPD)	CAP. COST ($)	O&M COST ($/YR)

				TREATMENT COSTS
BTS	TREATMENT	FLOW (GPD)	CAP. COST ($)	O&M COST ($/YR)
3	CARBON ADS	228400.	1003213.	84887.
4	SECONDARY	281000.	696504.	54862.

TABLE 37. COST OF SOURCE WATER

		GPD	$/1000 GAL	$/YEAR
1	COLO	739000.	.50	134868.
2	WELLS	603200.	.49	107882.

COST OF DISCHARGE

		GPD	$/1000 GAL	$/YEAR
1	DISCH	0.	.30	0.

TABLE 38. COST SUMMARY

	COST SUMMARY ($)	EXISTING FACILITIES COST ($)	NET COST ($)
Capital Cost of Pipe	269400.		
Capital Cost of Pumping	117779.		
Capital Cost of Storage	17856.		
Capital Cost of Regular Treatment	1699717.		
Capital Cost of Special Treatment	0.		
Total Capital Cost	2104752.		
Yearly Cost for Pipe	29679.		
Yearly Capital Cost for Pumping	12975.		
Yearly O&M Cost for Pumping	5344.		
Yearly Capital Cost for Storage	1967.		
Yearly Capital Cost for Regular Treatment	187255.		
Yearly O&M Cost for Regular Treatment	139748.		
Yearly Capital Cost for Special Treatment	0.		
Yearly O&M Cost for Special Treatment	0.		
Yearly Cost of Source Water	242750.		
Yearly Cost of Discharge	0.		
Total Yearly Cost	619718.		

V

SUBPOTABLE REUSE COMPUTER MODEL

SOFTWARE MODIFICATIONS

The subpotable reuse computer model, developed under a previous contract with the Air Force, was slightly modified to reflect Army water management options. This section describes these changes.

The major modification was the addition of a duplicate program to receive monthly flow data. The original program receives hourly flow data for each activity and simulates a typical 24-hour day, calculating all required storage, treatment, pumping, etc. This approach, however, did not address the questions of seasonal usage patterns, such as storage during rainy months or heavy irrigation during the summer. The best that could be done was to simulate a summer and a winter day, and extrapolate.

In addition to this daily program, an alternate program can now be selected that accepts monthly flow data and simulates an entire year of operation. This program is valuable in areas with large seasonal fluctuations due to climate or large man-power variations. This program provides a useful yearly water reuse summary showing seasonal storage requirements and treatment, as well as costs for the entire system. It may also be easier to use this alternate program at posts where hourly flow data is not available, but where monthly water use estimates are.

The modification for the monthly program was straightforward but time-consuming. It consisted of changing the time component, in all arrays with a time component, from 24 to 12, adjusting all time-dependent variables to reflect monthly rather than hourly flows, and changing all format statements to show months rather than hours.

Another modification to the original program was reduction of array size. Experience had shown that some of the arrays were much larger than required, and resulted in the use of excess core space and unnecessary costs. Two changes were made: the total number of activities that can be used in any single reuse system was reduced from 30 to 20, and the minimum number of contaminants involved was similarly reduced from 30 to 20. This allows the program to run at lower cost, and makes it possible to run on smaller machines.

Other changes were made to the input data concerning treatment units, performance, and cost. Since the Army operates predominantly trickling filter secondary plants, this system was added to the data base and used instead of activated sludge for

our test runs. Cost and performance data for ion exchange and simple clarification pretreatment were also added to provide more options for interactivity cascades.

All data on activities for our test runs was taken directly from our Army research and is representative of actual Army activities.

TEST RUN AT HYPOTHETICAL BASE

Introduction

In order to fully display the capabilities of the wastewater computer program (developed previously under Air Force Contract F 29601-75-C-0019), and to display its applicability to Army facilities, test runs were made for a hypothetical base called Overlord Army Base.

Test runs were made using both the daily simulation model and the yearly simulation model. The results highlighted here are for the yearly simulation run.

Input Data

The following data was used as input to the model for Overlord Army Base:

Constituents

BOD_5, COD, Phenol, SS, TDS, O&G, Cl, NO_3, NH_4, PO_4, Na, $CaCO_3$, Boron, Cyanide, Fe.

Activities

No.	Code	Name
1	BOIL	Boiler Plant
2	PHOTO	Photographic Processing Shop
3	PLATE	Plating Shop
4	TWR	Tank Wash Rack
5	HOUSE	Base Housing
6	SCRUB	Power Plant Scrubber
7	PAINT	Paint Shop
8	CLEAN	Steam Cleaning
9	DYNA	Dynamometer
10	GOLF	Golf Course

Regular Treatment Chains

The following treatment chains were supplied as data to the program for use at Blending-Treatment-Storage (BTS) units.

Code	Name
Primary	Primary Settling
Secondary	Trickling Filter (including primary and secondary clarification, and disinfection)
Filtration	Secondary with tertiary multimedia filtration
Carbon Ads	Secondary with tertiary multimedia filtration and carbon adsorption
Reverse Osmosis	Secondary with tertiary multimedia filtration, carbon adsorption, and reverse osmosis

Special Treatment at Activities

The following treatment units were supplied as input to the program for use as pretreatment at activities with strong wastes.

Code	Name
METAL REM	Metal Removal
OIL & GREASE	Oil and Grease Removal
SOFTENING	Water Softening
CHEM COAG	Chemical Coagulation and Solids Separation

This and other data, such as treatment removal efficiencies and minimum activity wastewater concentrations that require special treatment, are shown in Tables 39 through 42 extracted from the Phase I print out for Overlord Army Base.

Phase I

Phase I of the cascade computer program has been utilized to summarize water and wastewater volumes and characteristics for all the significant activities. The following tables extracted from the Phase I output illustrate this, using base housing as the activity. Table 43 shows the activity water demand and wastewater operation throughout the year. Note the increased water demand in summer for lawn watering. The graphs display the same information. Table 44 shows a water quality summary for base housing in mg/L and lbs/day generation. The first column "TOL" shows tolerable limits for supply water for base housing. Table 45 shows the effect of treatment on the base housing wastewater; and Table 46 shows the suitability of the base housing waste for reuse in other activities after various levels of treatment (an "X" denotes that the contaminant is acceptable for reuse in the designated activity). This data is provided for all activities in the Phase I output.

This phase of the program also determines potential cascades between activities at various levels of intermediate treatment. Table 47 displays the Phase I summary, showing which activity effluents can be reused, and which can be reused with the

TABLE 39

U.S. ARMY
SUB POTABLE WATER REUSE PROGRAM

OVERLORD ARMY BASE

LIST OF ACTIVITIES

1	BOIL	BOILER PLANT
2	PHOTO	PHOTO PROCESSING
3	PLATE	PLATING SHOP
4	TWR	TANK WASH RACK
5	HOUSE	BASE HOUSING
6	SCRUB	POWER PLANT SCRUBBER
7	PAINT	AINT SHOP/CORROSION
8	CLEAN	STEAM CLEANING
9	DYNA	DYNAMOMETER
10	GOLF	GOLF COURSE

TABLE 40

REQUIRED DISCHARGE QUALITY
(MG/L)

	DISCH
BOD	20.000
COD	40.000
PHNL	.100
SS	20.000
TDS	1200.000
O&G	5.000
CL	500.000
NO3	30.000
NH4	1.000
PO4	10.000
NA	250.000
CACO3	500.000
B	2.000
CN	.100
FE	5.000

TABLE 41

TREATMENT REMOVAL EFFICIENCIES

	PRIMARY	SECONDARY	FILTRATION	CARRON ADS	REV. OSMOS
BOD	30.%	85.%	95.%	99.%	100.%
COD	30.%	80.%	92.%	97.%	99.%
PHNL	30.%	75.%	75.%	92.%	92.%
SS	70.%	85.%	98.%	100.%	100.%
TDS	0.%	0.%	20.%	20.%	91.%
O&G	50.%	75.%	85.%	96.%	97.%
CL	0.%	0.%	0.%	0.%	80.%
NO3	0.%	0.%	0.%	20.%	70.%
NH4	0.%	80.%	98.%	100.%	100.%
PO4	0.%	20.%	85.%	85.%	98.%
NA	0.%	0.%	0.%	0.%	75.%
CACO3	0.%	0.%	0.%	0.%	90.%
B	10.%	10.%	10.%	10.%	75.%
CN	10.%	50.%	80.%	80.%	96.%
FE	10.%	40.%	60.%	60.%	96.%

SPECIAL TREATMENT REMOVAL EFFICIENCIES

	METAL REM	OIL&GREASE	SOFTENING	CHEM COAG
BOD	20.%	25.%	0.%	50.%
COD	20.%	30.%	0.%	50.%
PHNL	20.%	20.%	0.%	30.%
SS	20.%	60.%	0.%	70.%
TDS	0.%	0.%	0.%	0.%
O&G	20.%	75.%	0.%	20.%
CL	0.%	0.%	0.%	0.%
NO3	0.%	0.%	0.%	0.%
NH4	0.%	0.%	0.%	0.%
PO4	0.%	0.%	0.%	85.%
NA	0.%	0.%	0.%	0.%
CACO3	0.%	0.%	98.%	0.%
B	85.%	10.%	0.%	0.%
CN	85.%	10.%	0.%	0.%
FE	85.%	10.%	0.%	0.%

TABLE 42

MINIMUM SPECIAL TREATMENT CONCENTRATION LEVELS
(MG/L)

	METAL REM	OIL&GREASE	SOFTENING	CHEM COAG
BOD	-1.000	-1.000	-1.000	1000.000
COD	-1.000	-1.000	-1.000	2000.000
PHNL	-1.000	-1.000	-1.000	-1.000
SS	-1.000	-1.000	-1.000	1000.000
TDS	-1.000	-1.000	-1.000	-1.000
O&G	-1.000	200.000	-1.000	-1.000
CL	-1.000	-1.000	-1.000	-1.000
NO3	-1.000	-1.000	-1.000	-1.000
NH4	-1.000	-1.000	-1.000	-1.000
PO4	-1.000	-1.000	-1.000	100.000
NA	-1.000	-1.000	-1.000	-1.000
CACO3	-1.000	-1.000	500.000	-1.000
B	100.000	-1.000	-1.000	-1.000
CN	.500	-1.000	-1.000	-1.000
FE	100.000	-1.000	-1.000	-1.000

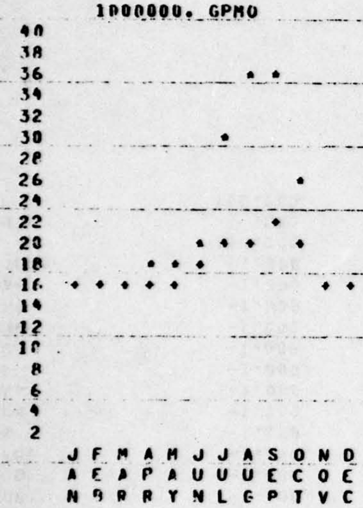
TABLE 43

ACTIVITY WATER DEMAND AND WASTEWATER GENERATION

BASE: OVERLORD ARMY BASE
ACTIVITY: BASE HOUSING
ACTIVITY CODE: HOUSE

MONTH	WATER IN (1000 G/MO)	WASTEWATER OUT (1000 G/MO)	CUMULATIVE IN (1000 GAL)	CUMULATIVE OUT (1000 GAL)
JAN	15000.	15000.	15000.	15000.
FEB	15000.	15000.	30000.	30000.
MAR	15000.	15000.	45000.	45000.
APR	18000.	16000.	63000.	61000.
MAY	18000.	16000.	81000.	77000.
JUN	20000.	18000.	101000.	95000.
JUL	30000.	20000.	131000.	115000.
AUG	35000.	20000.	166000.	135000.
SEP	35000.	22000.	201000.	157000.
OCT	25000.	19000.	226000.	176000.
NOV	15000.	15000.	241000.	191000.
DEC	15000.	15000.	256000.	206000.

1000000. GPMO



10000000. GAL

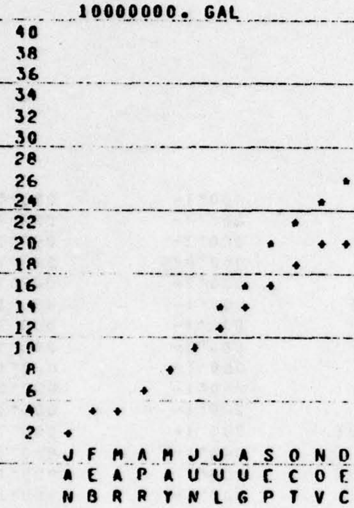


TABLE 44

WATER QUALITY SUMMARY

BASE: OVERLORD ARMY BASE
ACTIVITY: BASE HOUSING
ACTIVITY CODE: HOUSE

	TOL(MG/L)	IN(MG/L)	OUT(MG/L)	DEGR(MG/L)	IN(LBS/DAY)	OUT(LBS/DAY)	DEGR(LBS/DAY)
BOD	1.000	.100	200.000	199.900	.585	941.420	940.835
COD	3.000	1.000	300.000	299.000	5.850	1412.130	1406.280
PHNL	.001	.001	.150	.149	.006	.706	.700
SS	1.000	1.000	200.000	199.000	5.850	941.420	935.570
TDS	1000.000	600.000	900.000	300.000	3509.760	4236.390	726.630
O&G	.100	.100	.500	.400	.585	2.354	1.769
CL	250.000	185.000	340.000	155.000	1082.176	1600.414	518.238
NO3	45.000	5.000	10.000	5.000	29.248	47.071	17.823
NH4	.100	.100	30.000	29.900	.585	141.213	140.628
PO4	3.000	3.000	3.000	0.000	17.549	14.121	-3.428
NA	250.000	70.000	72.000	2.000	409.472	338.911	-70.561
CACO3	200.000	150.000	160.000	10.000	877.440	753.136	-124.304
B	.100	.100	.100	0.000	.585	.471	-.114
CN	.200	.005	.010	.005	.029	.047	.018
FE	.300	.300	.300	0.000	1.755	1.412	-.343

TABLE 45

ACTIVITY WASTEWATER CONCENTRATIONS AFTER TREATMENT
(MG/L)

BASE: OVERLORD ARMY BASE
ACTIVITY: BASE HOUSING
ACTIVITY CODE: HOUSE
SPECIAL TREATMENT: NONE

	NONE	PRIMARY	SECONDARY	FILTRATION	CARBON ADS	REV. OSMOS
BOD	200.000	140.000	30.000	10.000	2.000	0.000
COD	300.000	210.000	60.000	24.000	9.000	3.000
PHNL	.150	.105	.038	.038	.012	.012
SS	200.000	60.000	30.000	4.000	0.000	0.000
TDS	900.000	900.000	900.000	720.000	720.000	81.000
O&G	.500	.250	.125	.075	.020	.015
CL	340.000	340.000	340.000	340.000	340.000	68.000
NO3	10.000	10.000	10.000	10.000	8.000	3.000
NH4	30.000	30.000	6.000	.600	0.000	0.000
PO4	3.000	3.000	2.400	.450	.450	.060
NA	72.000	72.000	72.000	72.000	72.000	18.000
CACO3	160.000	160.000	160.000	160.000	160.000	16.000
B	.100	.090	.090	.090	.090	.025
CN	.010	.009	.005	.002	.002	.000
FE	.300	.270	.180	.120	.120	.012

TABLE 46

SUITABILITY OF ACTIVITY EFFLUENT FOR REUSE

```
BASE:                OVERLORD ARMY BASE
ACTIVITY:            BASE HOUSING
ACTIVITY CODE:       HOUSE
SPECIAL TREATMENT:   NONE

             NONE          PRIMARY       SECONDARY     FILTRATION    CARBON ADS    REV. OSMOS

             BPPTHSPCDG    BPPTHSPCDG    BPPTHSPCDG    BPPTHSPCDG    BPPTHSPCDG    BPPTHSPCDG
             OHLWOCALYO    OHLWOCALYO    OHLWOCALYO    OHLWOCALYO    OHLWOCALYO    OHLWOCALYO
             IOARURIENL    IOARURIENL    IOARURIENL    IOARURIENL    IOARURIENL    IOARURIENL
             LTT SUNAAF    LTT SUNAAF    LTT SUNAAF    LTT SUNAAF    LTT SUNAAF    LTT SUNAAF
              OE EBTN       OE EBTN       OE EBTN       OE EBTN       OE EBTN       OE EBTN

BOD                                           XXX X        X XXXXX       X XXXXX    XXXXXXXXXX
COD                                           XXX X        X XXX X       X XXXXX    X XXXXXXXX
PHNL            X XXXXX       X XXXXX    X  X XXXXX    X  X XXXXX    X  X XXXXX    X  X XXXXX
SS                              XXX           XXX X    X  X XXXXX    XXXXXXXXXX    XXXXXXXXXX
TDS           XXXXXXXX      XXXXXXXX      XXXXXXXX      XXXXXXXX      XXXXXXXX    XXXXXXXXXX
O&G          X  X XXXXX    X  X XXXXX    X  X XXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX
CL              X XXX X       X XXX X       X XXX X       X XXX X       X XXX X    XXXXXXXXXX
NO3          XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX
NH4                  X             X          XXXXX       X XXXXX    XXXXXXXXXX    XXXXXXXXXX
PO4          XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX
NA           X XXXXXXXX    X XXXXXXXX    X XXXXXXXX    X XXXXXXXX    X XXXXXXXX    XXXXXXXXXX
CACO3         XXXXXXX X     XXXXXXX X     XXXXXXX X     XXXXXXX X     XXXXXXX X    XXXXXXXXXX
B            XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX
CN           X XXXXXXXX    X XXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX
FE           XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX    XXXXXXXXXX
```

TABLE 47

BASE SUMMARY
ACCEPTABLE CASCADES AT VARIOUS LEVELS OF TREATMENT

BASE: OVERLORD ARMY BASE

```
                    NONE            PRIMARY         SECONDARY       FILTRATION      CARBON ADS      REV. OSMOS

                    BPPTHSPCDG      BPPTHSPCDG      BPPTHSPCDG      BPPTHSPCDG      BPPTHSPCDG      BPPTHSPCDG
                    OHLWOCALYO      OHLWOCALYO      OHLWOCALYO      OHLWOCALYO      OHLWOCALYO      OHLWOCALYO
                    IOARURIENL      IOARURIENL      IOARURIENL      IOARURIENL      IOARURIENL      IOARURIENL
                    LTT SUNAAF      LTT SUNAAF      LTT SUNAAF      LTT SUNAAF      LTT SUNAAF      LTT SUNAAF
                     OE ERTN         OE ERTN         OE EBTN         OE EBTN         OE EBTN         OE EBTN

BOIL                      XX              XX              XX              XX              XX        X 1X1XXXXX
... SOFTENING          2  XX           2  XX           2  XX           2  XX           2  XX        X 1X1XXXXX
PHOTO                    2               2               122 2         2 111 1         1 111 1      1  X XXXX1
... METAL REM            2               1             2 XXX 1         X XXX21         X XXX21      X 1X1XXXX1
PLATE                  X XXX2X         X XXX2X      2  X XXX2X      2  X XXX1X      221X1XXX1X      XXXXXXXXXX
TVP                                                      X               X11 1         1 XXX X      222X2XXX1X
HOUSE                                                    XXX X         X XXX X         X XXX2X      X21X1XXXXX
SCRUB                     22              22             222             111           1 1XX 2      111X1XXXXX
... CHEM COAG             22              22             222             1XX 2         1 1XX 2      111X1XXXXX
PAINT                                                                    2               122 2      2  2 X1121
... OIL&GREASE                           2               222 2           222 2         2 122 2      2  1 X1121
... CHEM COAG                                                            2               122 2      2  2 X1121
CLEAN                                                                    2               111           2 XXX21
... OIL&GREASE                                            22             122           2 1XX           X XXX11
... SOFTENING                                                            2               111           2 XXX21
... CHEM COAG                                            2               122             1XX 2         1 XXX1X
DYNA                      XX              XX              XX 2            XX 2            XX 2      X21X1XXXXX
... SOFTENING            2XX           2 2XX           2 2XX 2         2 2XX 2         2 2XX 2      X21X1XXXXX
```

exception of one or two problem contaminants. An "X" means the cascade is totally acceptable. A "1" or "2" means that one or two contaminants are not acceptable for the cascade. For example, locating "HOUSE" on the left and following across the rows, shows that base housing effluent is acceptable for reuse in the air pollution scrubber, the paint shop, steam cleaning, and golf course. Filtration adds the tank wash rack as an acceptable reuse, and so on. This summary is extremely helpful in laying out cascade networks for input to Phase II of the computer program.

Phase II

With the aid of Phase I output, alternative cascade reuse networks were developed for Phase II of the reuse program. The figures on the following pages display three wastewater reuse networks evaluated for Overlord Army Base.

Network No. 1

Network No. 1 shows a no-reuse situation, with effluent from the STP being discharged to surface water.

Network No. 2

Network No. 2 shows reuse for golf course irrigation only; all other activities use fresh water and discharge to the STP as usual.

Network No. 3

Network No. 3 shows a complex reuse scheme. Wastewater from the boiler plant is reused for air scrubbing; plating shop effluent is reused in the paint shop water wall and the dynamometer; and finally, the effluent from the STP is reused for tank washing and irrigation of the golf course.

Phase II provides a wealth of cost information for each network:

- Piping
- Pumping
- Storage
- Regular treatment
- Water supply.

These costs are then summarized for comparative purposes as shown in the following three tables that give the costs for the three networks just illustrated.

As shown, Network 2 (reuse for golf course irrigation) has the lowest annual cost at $509,754. This represents an annual

TABLE 48

NETWORK 1

	COST SUMMARY ($)	EXISTING FACILITIES COST ($)	NET COST ($)
CAPITAL COST OF PIPE	0.		
CAPITAL COST OF PUMPING	121888.		
CAPITAL COST OF STORAGE	0.		
CAPITAL COST OF REGULAR TREATMENT	1257611.		
CAPITAL COST OF SPECIAL TREATMENT	63436.		
TOTAL CAPITAL COST	1442935.		
YEARLY COST FOR PIPE	0.		
YEARLY CAPITAL COST FOR PUMPING	13428.		
YEARLY O&M COST FOR PUMPING	6369.		
YEARLY CAPITAL COST FOR STORAGE	0.		
YEARLY CAPITAL COST FOR REGULAR TREATMENT	138549.		
YEARLY O&M COST FOR REGULAR TREATMENT	75160.		
YEARLY CAPITAL COST FOR SPECIAL TREATMENT	6989.		
YEARLY O&M COST FOR SPECIAL TREATMENT	6918.		
YEARLY COST OF SOURCE WATER	287834.		
YEARLY COST OF DISCHARGE	0.		
TOTAL YEARLY COST	535247.		

TABLE 49

NETWORK 2

	COST SUMMARY ($)	EXISTING FACILITIES COST ($)	NET COST ($)
CAPITAL COST OF PIPE	93671.		
CAPITAL COST OF PUMPING	112323.		
CAPITAL COST OF STORAGE	894555.		
CAPITAL COST OF REGULAR TREATMENT	1257611.		
CAPITAL COST OF SPECIAL TREATMENT	63436.		
TOTAL CAPITAL COST	2371595.		
YEARLY COST FOR PIPE	4811.		
YEARLY CAPITAL COST FOR PUMPING	12374.		
YEARLY O&M COST FOR PUMPING	5066.		
YEARLY CAPITAL COST FOR STORAGE	98553.		
YEARLY CAPITAL COST FOR REGULAR TREATMENT	138549.		
YEARLY O&M COST FOR REGULAR TREATMENT	75160.		
YEARLY CAPITAL COST FOR SPECIAL TREATMENT	6989.		
YEARLY O&M COST FOR SPECIAL TREATMENT	6918.		
YEARLY COST OF SOURCE WATER	161334.		
YEARLY COST OF DISCHARGE	0.		
TOTAL YEARLY COST	509754.		

TABLE 50

NETWORK 3

	COST SUMMARY (\$)	EXISTING FACILITIES COST (\$)	NET COST (\$)
CAPITAL COST OF PIPE	50767.		
CAPITAL COST OF PUMPING	133610.		
CAPITAL COST OF STORAGE	863739.		
CAPITAL COST OF REGULAR TREATMENT	2504111.		
CAPITAL COST OF SPECIAL TREATMENT	63436.		
TOTAL CAPITAL COST	3615664.		
YEARLY COST FOR PIPE	5593.		
YEARLY CAPITAL COST FOR PUMPING	14720.		
YEARLY O&M COST FOR PUMPING	5778.		
YEARLY CAPITAL COST FOR STORAGE	95158.		
YEARLY CAPITAL COST FOR REGULAR TREATMENT	275873.		
YEARLY O&M COST FOR REGULAR TREATMENT	149834.		
YEARLY CAPITAL COST FOR SPECIAL TREATMENT	6989.		
YEARLY O&M COST FOR SPECIAL TREATMENT	6918.		
YEARLY COST OF SOURCE WATER	158784.		
YEARLY COST OF DISCHARGE	0.		
TOTAL YEARLY COST	719646.		

savings of about $25,000/year over the no-reuse situation in Network 1. Network 3 costs are much higher due to more stringent treatment requirements necessitating activated carbon adsorption.

The beauty of the computer model is that many different networks with slight variation can be evaluated very quickly.

VI.

REFERENCES

1. TM 5-814-6 Sanitary Engineering - Industrial Wastes (October, 1965).

2. Benson, L. J., M. Staub, R. Fileccia, and J. Matherly. 1977. Recommended Design Criteria for Wastewater Treatment at Proposed Consolidated Tactical Vehicle Wash Facility, Fort Drum, New York. Interim Report N-26, Department of the Army, Construction Engineering Research Laboratory. 64 pp.

3. Fileccia, R. J., L. J. Benson, K. A. Conley, and J. E. Matherly. 1976. Vehicle Washing Operations and Wastewater Discharges, Fort Drum, New York. Findings and Recommendations. Technical Report E-80. Department of the Army Construction Engineering Research Laboratory, Champaign, Illinois. 47 pp.

4. United States Air Force Environmental Health Laboratory. Industrial Waste and Water Pollution Surveys (for various Air Force bases). United States Air Force Environmental Health Laboratory, Kelly Air Force Base, Texas.

5. United States Environmental Protection Agency. 1976. National Interim Primary Drinking Water Regulations. EPA-570/9-76-003. United States Environmental Protection Agency, Washington, D.C. 159 pp.

6. United States Public Health Service. Drinking Water Standards of 1962.

7. Sundaram, T. R., and J. E. Santo. 1977. The Development of a Hydroperm Microfiltration System for the Treatment of "MUST" Hospital Wastewater Effluents. For: U. S. Army Medical Research and Development Command, Fort Detrick, Maryland. HYDRONAUTICS, Inc.

8. Schanche, G. W., J. R. Cannon, L. R. Greep, and B. A. Donahue. 1976. Characterization of Wastes from Army Installations, Pollution Estimation Factors. Department of the Army Construction Engineering Research Laboratory. 26 pp.

9. McKee, J. E., and H. W. Wolf. 1971. Water Quality Criteria, Second Edition. California State Water Resources Control Board. 548 pp.

10. United States Environmental Protection Agency. 1973. Water Quality Criteria, 1972. Ecological Research Series No. R3-73-033. United States Environmental Protection Agency.

11. United States Environmental Protection Agency. 1977. State and Local Pretreatment Programs, Vol. III.

12. The Redux Corporation. 1977. Redux Laundry Water Recycling System Saves Water, Money, and Energy; Stops Pollution. Arundale, Inc., St. Louis, Missouri.

13. Santo, J. E., J. H. Duncan, H. L. Liu, and N. I. Shapira. 1979. Regeneration of Wastewaters for Reuse through Hydroperm Microfiltration. Hydronautics, Inc., Laurel, Maryland.

14. United States Environmental Protection Agency. 1974. Draft Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Auto and Other Laundries Point Source Category. (Unpublished.)

15. Nemerow, N. L. 1971. Liquid Waste of Industry. Addison-Wesley Publishing Company, Reading, Massachusetts. 584 pp.

16. U.S. Army Environmental Hygiene Agency. 1975. Water Quality Engineering Special Study No. 24-077-74/76, Industrial Waste, Letterkenny Army Depot, Chambersburg, Pennsylvania, 5-22 August, 1974. U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland. 23 pp.

17. Matherly, J. E., R. J. Fileccia, and H. A. Porte. 1974. Industrial Wastewaters, Red River Army Depot, Texarkana, Texas. Technical Report E-24. Department of the Army Construction Engineering Research Laboratory, Champaign, Illinois. 77 pp.

18. U. S. Army Environmental Hygiene Agency. 1978. Final Report, Water Quality Engineering Special Study No. 24-0068-78, Industrial Wastes, Corpus Christi Army Depot, Corpus Christi, Texas, 4-18 November 1977, 16-20 January, and 13-17 February 1978. U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland.

19. United States Environmental Protection Agency -- Technology Transfer. 1973. Waste Treatment, Upgrading Metal-Finishing Facilities to Reduce Pollution. Environmental Protection Agency Technology Transfer Seminar Publication. 27 pp.

20. Shelton, S. P., E. C. Frein, and P. S. Daley. 1976. Draft Report on Water Reuse at Air Force Electroplating Facilities. Water and Solid Waste Resources Division, Environics Directorate, Air Force, Civil Engineering Center, Tyndall Air Force Base. 14 pp.

21. Schmidt, C. J., and E. V. Clements. 1975. Demonstrated Technology and Research Needs for Reuse of Municipal Wastewater. Environmental Protection Agency - 670/2-75-038. United States Environmental Protection Agency, Cincinnati, Ohio. 339 pp.

12. The Redux Corporation. 1977. Redux Laundry Water Recycling System Saves Water, Money, and Energy; Stops Pollution. Arundale, Inc., St. Louis, Missouri.

13. Santo, J. E., J. H. Duncan, H. L. Liu, and N. I. Shapira. 1979. Regeneration of Wastewaters for Reuse through Hydroperm Microfiltration. Hydronautics, Inc., Laurel, Maryland.

14. United States Environmental Protection Agency. 1974. Draft Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Auto and Other Laundries Point Source Category. (Unpublished.)

15. Nemerow, N. L. 1971. Liquid Waste of Industry. Addison-Wesley Publishing Company, Reading, Massachusetts. 584 pp.

16. U.S. Army Environmental Hygiene Agency. 1975. Water Quality Engineering Special Study No. 24-077-74/76, Industrial Waste, Letterkenny Army Depot, Chambersburg, Pennsylvania, 5-22 August, 1974. U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland. 23 pp.

17. Matherly, J. E., R. J. Fileccia, and H. A. Porte. 1974. Industrial Wastewaters, Red River Army Depot, Texarkana, Texas. Technical Report E-24. Department of the Army Construction Engineering Research Laboratory, Champaign, Illinois. 77 pp.

18. U. S. Army Environmental Hygiene Agency. 1978. Final Report, Water Quality Engineering Special Study No. 24-0068-78, Industrial Wastes, Corpus Christi Army Depot, Corpus Christi, Texas, 4-18 November 1977, 16-20 January, and 13-17 February 1978. U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland.

19. United States Environmental Protection Agency -- Technology Transfer. 1973. Waste Treatment, Upgrading Metal-Finishing Facilities to Reduce Pollution. Environmental Protection Agency Technology Transfer Seminar Publication. 27 pp.

20. Shelton, S. P., E. C. Frein, and P. S. Daley. 1976. Draft Report on Water Reuse at Air Force Electroplating Facilities. Water and Solid Waste Resources Division, Environics Directorate, Air Force, Civil Engineering Center, Tyndall Air Force Base. 14 pp.

21. Schmidt, C. J., and E. V. Clements. 1975. Demonstrated Technology and Research Needs for Reuse of Municipal Wastewater. Environmental Protection Agency - 670/2-75-038. United States Environmental Protection Agency, Cincinnati, Ohio. 339 pp.

22. U.S. Army Environmental Hygiene Agency. 1977. Water Quality Engineering Special Study No. 24-0656-77. Industrial Wastewater Treatment, Anniston Army Depot, Anniston, Alabama. 16 October - 1 November, 1976. U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland.

23. SCS Engineers. 1977. Cascade Water Reuse. CEEDO-TR-77-19. U.S. Air Force, Tyndall AFB, Florida.

VII

APPENDICES

APPENDIX A

WATER REUSE EVALUATION MODEL

TIER I
TIER II
TIER III

ARMY WASTEWATER REUSE POTENTIAL EVALUATION MODEL

TIER I

General

Base Name: ______________________________

Location: ______________________________

Date: ______________________________

Name and Organization of Evaluator: ______________________

Key Contacts at Base:

Name	Phone	Autovon

Instructions:

Answer each question as accurately as possible, using engineering estimates if actual data is not available. Circle the correct answer, total the points, and check your total score against the reuse potential ranges at the end.

Note the column for "Key Question." If that column has an asterisk, then that question is particularly important. If answered positively, the post may have good potential for reuse even if its total score does not indicate such.

Category	Points 0	1	2	3	4	5	6	7	8	9	Key Question
I. WATER SUPPLY											
1. Is the base water supply available from a reliable source for the next 20 years?	YES				NO						
2. Is there possible significant depletion of the water supply within the next 10 years?	NO						YES				

Category	Points 0	1	2	3	4	5	6	7	8	9	Key Question
I. (continued)											
3. Is there an anticipated problem with the water supply within 5 years?	NO									YES	*
4. What is the present cost of water procurement and treatment per 1,000 gallons?	$ <0.10		$ 0.10 0.20		$ 0.20 0.30		$ 0.30 0.40		$ >0.40		
5. Is there a foreseeable event that could markedly increase water costs in the next 10 years?	NO					YES					
6. Is expansion or upgrading of the water supply/treatment system planned in the next 10 years?	NO			YES							*
7. What volume of water is used on the average in MGD?	<1		1-2		>2						
8. What is the TDS (mg/ℓ) of the base water supply?	>800	500-800	200-500		<200						

Comments:

Subtotal Points WATER SUPPLY: ______

Category	Points 0	1	2	3	4	5	6	7	8	9	Key Question
II. WASTEWATER											
9. Does the base treat wastewater for direct discharge to surface water or land?	NO							YES			
Answer questions 10-13 for Base STP only											
10. Does the treatment plant presently meet discharge requirements?	YES						NO				*

Category	Points 0	1	2	3	4	5	6	7	8	9	Key Question
II. (continued)											
11. Will additional treatment facilities be required within the next 5 years?	NO				YES						*
12. What quality is the plant effluent in terms of BOD (mg/ℓ)?	>30		20-30		10-20		<10				
13. What percentage of design capacity is in use?	<50	50-75	75-100	>100							
Answer questions 14-16 for Base IWTP only											
14. Does the treatment plant presently meet discharge requirements?	YES						NO				*
15. What quality is the plant effluent in terms of COD (mg/ℓ)?	>200		100-200		50-100		<50				
16. Are discharge limits set for specific contaminants (i.e., heavy metals, CN, nutrients)?	NO			YES							
17. What total quantity of wastewater (treated and untreated) is discharged from the base in MGD?	>.5	.5-1.0	1-2	>2							
18. If the base discharges to a municipal or regional sewer system, what is the discharge fee per MG?	$ <100	$ 100-200		$ 200-300		$ 300-400		$ >400			
19. Are future changes likely that would markedly increase the discharge fee?	NO				YES						

Comments: Subtotal Points

WASTEWATER DISCHARGE: ______________

Category	Points 0	1	2	3	4	5	6	7	8	9	Key Question
III. ACTIVITIES											
20. Does the base have a golf course?	NO				YES						
21. Is the golf course irrigated?	NO			YES							
22. How many acres of landscape and athletic fields could be irrigated if reclaimed water were available?	0	0-20	20-40	40-80	>80						
23. How many large industrial cooling towers does the base have? (1)	0	1-5	5-15	>15							
24. If the base has a plating shop, how much wastewater does it discharge in 1,000 gal/day? (1)		<10	10-50	50-100	>100						
25. Does the base have air pollution wet scrubbers?	NO	YES									
26. Does the base have a vehicle wash rack(s)? (1)	NO		YES								
27. Does the base have a paint shop with a water wall? (1)	NO	YES									
28. Does the base perform wet sand-blasting?	NO	YES									
29. Does the base have an industrial laundry? (1)	NO		YES								
30. Does the base have a photo lab?	NO	YES									
31. Does the base contain any type of artificially filled recreational lakes?	NO			YES							

Category	Points 0	1	2	3	4	5	6	7	8	9	Key Question
III. (continued)											
32. Does the base have steam cleaning facilities?	NO	YES									
33. Does the base generate its own electrical power?	NO			YES							
34. Does the base have a central energy facility for generation of steam for heating and cooling?	NO		YES								
35. Does the base have a large pesticide management program?	NO	YES									
36. Does the base have any other activities using more than 25,000 gpd that we have not included? (Point assessment is left to evaluator.)											

(1) If the base has this activity, please refer to the activity descriptions in the main report. This activity has been highlighted as having potential for internal recycle as either a water conservation or pollution control measure. Details of treatment/recycle schemes are provided in the main report.

Comments:

Subtotal Points

ACTIVITIES: ____________________

Category	Points 0	1	2	3	4	5	6	7	8	9	Key Question
IV. INSTITUTIONAL ASPECTS											
37. Is the base free of any long-term water purchase agreements that would prohibit the base from cutting back on water usage?	NO				YES						

Category	Points 0	1	2	3	4	5	6	7	8	9	Key Question
IV. (continued)											
38. Is the base free of any water laws (i.e., Doctrine of Prior Appropriation) or commitments to regional wastewater systems that would prohibit a reduction in volume of effluent discharged?	NO				YES						
39. Is wastewater reuse occurring now or being planned in surrounding communities?	NO					YES					
40. What percentage of the total wastewater generated on base is currently being reused?	0		0-10		10-50		>50				
41. Is there a potentially large civilian user near the base (i.e., golf course, power plant, agriculture)?	NO				YES						
42. Are key base personnel interested in using reclaimed water?	NO	SLIGHTLY			MODERATELY				HIGHLY		

Comments:

Subtotal Points

INSTITUTIONAL: ______________________

Category	Points 0	1	2	3	4	5	6	7	8	9	Key Question
V. CLIMATE											
43. What is the average yearly rainfall on the base in inches/year?	>40		30-40		20-30			10-20		<10	

Category	Points										Key Question
	0	1	2	3	4	5	6	7	8	9	
V. (continued)											
44. What is the average yearly pan evaporation on the base in inches/year?	20-30		30-40		40-60		60-80			>80	

Comments:

Subtotal Points

CLIMATE: ____________

TOTAL POINTS: ____________

SCORE INTERPRETATION

The final point total reflects the following wastewater reuse potential for the base:

1. 0 to 54 points: The base has little or no potential for reusing wastewater on a system-wide scale, and no further reuse evaluation is necessary at this point.

2. 55 to 74 points: The base has marginal potential for reuse on a system-wide scale. The decision as to whether Tier II should be applied will depend on 1) whether the score was high or low in the category; and 2) the judgement of the evaluator. Although they don't score highly overall, some bases may have a compelling reason for pursuing reuse to Tier II, i.e., one or more "Key Questions" may have been answered positively. For example, a base with a critical water supply crisis may opt for a deeper look at reuse even though its score in other categories was not exceptional.

3. 75 to 100 points: The base has good reuse potential on a system-wide basis. Proceed to Tier II of the reuse evaluation process.

4. >100 points: The base has excellent reuse potential on a system-wide basis. Proceed to Tier II and note good possibility for Tier III application.

ARMY
WASTEWATER REUSE POTENTIAL
EVALUATION MODEL

TIER II

GENERAL

- Base Name: ______________________________
- Location: ______________________________
- Date: ______________________________
- Name of Evaluator: ______________________
- Key Contacts at Base: ____________________

Name	Phone	Autovon

- Instructions

  Follow through the four sections of the Tier II evaluation. Provide required data and make engineering decisions as accurately as possible. Where necessary for clarity, background data and examples have been provided. Be aware that considerable engineering judgement is required, especially on Section 3.

  Note the importance of talking to the post planning section on future developments scheduled for the base: old activities may be phased out, new ones brought on-line, changes in mission may be planned. Any of these can drastically change water use/generation patterns.

SECTION 1 - ACTIVITIES

This section of the Tier II evaluation provides background information on activities, and contains forms for collecting specific base data. Background information on activities can also be found in the Activities Section of this report. The Activities Section describes Army activities which are significant water users and/or wastewater generators. Typical flow rates and effluent quality data, and the general water quality required for supply water to various activities, are given. The numbers pro-

vided are typical values based on combined data. The values for any specific base may vary; it is best to obtain actual field data rather than to rely on average numbers from the report.

Activity Summary

Table A-1 shows a comprehensive list of typical water- and wastewater-related activities on Army posts. The activities are not of equal importance in terms of flow volume and reuse potential, but all are included for completeness.

Most Important Army Post Potential Sources of Reclaimed Water

Those activities best suited for inclusion in a Tier II reuse scheme as potential sources of reclaimed water are listed in Table A-2. The characteristics of good potential wastewater source are:

- High volume: The wastewater volume should be high enough for reuse to be economical due to freshwater savings and/or wastewater discharge reduction.

- Reliable flow: The wastewater flow should be predictable so that storage needs can be determined and a reliable supply provided to the user activities.

- Low contamination: The wastewater should not be so highly contaminated that prohibitively expensive treatment would be needed before reuse.

Some industrial wastewaters, e.g., steam cleaning and metal cleaning wastes, require extensive waste treatment before reuse to remove or neutralize such diverse contaminants as oils, grease, cyanides, phenols, heavy metals, phosphates, acids, and caustics, and therefore have very low reuse potential. However, other industrial effluents, e.g., some plating shop rinse waters and cooling system blowdowns, meet the above criteria and are good candidates for reuse.

Sanitary and domestic-type wastewaters from housing, community, protective, administrative/institutional, and commercial activities also have excellent reuse potential. At most Army posts, these wastewaters are collected by the sanitary sewer system into a single sewage flow which can often be reused after secondary or tertiary treatment in a sewage treatment plant. A well-operating post sewage treatment plant improves the economics of reuse considerably. Industrial waste treatment plant effluents can also be reused if the treatment is complete and effective. IWTP effluent is advantageous because both bacterial and viral contamination can be very low. However, before reuse, oils and dissolved metals and salts must often be removed from these waters.

TABLE A-1
TYPICAL WATER AND WASTEWATER RELATED ACTIVITIES AT ARMY POSTS

Community	Protective	Administrative/Institutional	Industrial	Wastewater Management
Mess Halls	Police Station	Unclassified Office Space	Vehicle Wash Racks	Sewage Treatment
Non-Commissioned Officers' Club	Fire Staion	Shipping and Receiving Facilities	Aircraft Wash	Industrial Waste Treatment
Officers Club	Fire-Fighting Practice Area	Communications Facilities	Steam Cleaning	
Elementary and High Schools	Jail	Command-Level Headquarters	Metal Plating and Finishing	Waste Water Disposal
Playgrounds, Parks		Radar Installaions	Autoclaves	
Chapel		Military Training and Instruction Facilities	Boilers	
Gymnasium	**Water Supply**		Metal Cleaning	
Atheletic Fields	Source		Paint Booth Water Walls	
Swimming Pool	Treatment	**Commercial**	Air Pollution Wet Scrubbers	**Housing**
Auditorium		Commissary	Laboratories	*Family Housing*
Hobby Shop		Post Exchange	Cooling Towers	Baracks
Golf Course		Gas Station	Dynamometers	Bachelor Officers' Quarters
Library		Laundromats	Engine Test Cells	
Bowling Alley		Restaurants, Cafetarias	Ash Handling Systems	Visiting Officers'
Recreational Lakes and Ponds		Post Office	Industrial Laundries	
Hospital/Clinic		Bank	Pesticide Management Area	
Landscape Irrigation			Photographic Laboratory	

TABLE A-2. ARMY ACTIVITIES WITH GREATEST POTENTIAL AS SOURCES OF RECLAIMED WATER

Housing, Community, Protective, Administrative/Institutional, and Commercial*	Industrial	Wastewater Management
	Vehicle Wash Racks	Sewage Treatment Plant Effluent
	Aircraft Wash Racks	Industrial Waste Treatment Plant Effluent
	Metal Plating and Finishing	
	Cooling Towers	
	Dynamometers	
	Industrial Laundries	
	Boilers	

*The total sewage flow from these activities should be considered as one wastewater source

Most Important Army Post Potential Users of Reclaimed Water

Table A-3 lists those activities best suited for inclusion in a Tier II reuse scheme as potential users of reclaimed water. Characteristics of a good potential user of reclaimed water are:

- Low quality demands: The best users of reclaimed water are those that can utilize good secondary effluent because it is usually available and not expensive to produce. Activities that can make use of filtered secondary effluent also have good potential, because most secondary plants can be readily upgraded with filtration, although this is more expensive. Activities that require very high water quality, e.g., boilers, are generally poor users because the technology to purify wastewater is too expensive in most cases. Although we are considering only nonpotable reuse, bacteria and viruses in the reclaimed water can be a hazard in those activities that involve human contact with water sprays and aerosols. Such activities include wash and steam racks, paint water walls, and, to a lesser extent, spray irrigation of golf courses and landscape. Reclaimed water for these activities must meet required bacterial and viral levels.

- High volume: Good potential users are those that use significant amounts of water on a regular basis. Activities such as irrigation can use tremendous volumes of reclaimed water, but frequently require large storage basins to hold the water during high precipitation periods, e.g., the winter months in California. Activities that use a great deal of water continuously, such as industrial cooling towers, are optimal.

Most Important Army Post Activities with Potential for Internal Recycling

Those activities that are best suited for internal recycling are listed in Table A-4. Preferred attributes for internal recycling include:

- Good effluent quality and/or low water quality requirements: Activities with a fairly clean discharge, or one that is simply treated, have good potential for internal recycling.

- High volume: Activities using large volumes of water offer economies of scale for pretreatment systems. Small water savings gained by internal treatment and recycling are rarely economically feasible.

Tier II Activity Information Form

A data sheet (Exhibit A) should be filled out for each important activity on the base. Water usage and wastewater genera-

TABLE A-3. ARMY ACTIVITIES WITH GREATEST POTENTIAL AS USERS OF RECLAIMED WATER

Community	Commercial	Industrial
Golf Course Irrigation	Laundry	Cooling Towers
Landscape Irrigation		Paint Booth Water Walls
Athletic Field, Playground, Park Irrigation		Air Pollution Wet Scrubbers
Recreational Lakes and Ponds		Autoclaves
		Dynamometers
		Vehicle Wash Racks
		Aircraft Wash Racks
		Steam Cleaning
		Ash Handling System Water
		Maintenance Wash Downs

TABLE A-4. ARMY ACTIVITIES WITH GREATEST POTENTIAL FOR INTERNAL RECYCLING

Industrial Activities
Metal Plating and Finishing
Vehicle Wash Racks
Aircraft Wash Racks
Dynamometers
Large Industrial Autoclaves
Cooling Towers
Paint Booth Water Walls
Air Pollution Wet Scrubbers

EXHIBIT A
ACTIVITY INFORMATION FORM

Recorder__________________________ Date____________

1. ACTIVITY NAME__________________________________BLDG. NO.______

2. LOCATION(S)____

____

3. KEY PERSON(S)____

____

4. MAILING ADDRESS____

___________________TELEPHONE___________________

5. DESCRIPTION OF ACTIVITY____

____

____

____

6. WATER USAGE

- Average daily usage______________________(gpd)
- Per unit usage (e.g., gal/vehicle washed)_______________

____

- Seasonal usage pattern (due to climate or manpower flux)

____

- How was data obtained?____

____

7. WASTEWATER GENERATION

- Average daily generation_________________(gpd)
- Per unit generation____

- Seasonal generation pattern (due to climate or manpower flux) ______

- How was data obtained? ______

8. FUTURE

- Will the activity be operating in the same mode in the future? ______

- Are new units expected to come on line? ______

tion data can be obtained from existing records by observation and simple measurements, or by estimating flow volumes. Data contained in the Activities Section of this report are typical values, and the data for a particular base may vary.

SECTION 2 - SPATIAL RELATIONSHIPS

The purpose of this section is to guide the Tier II evaluator in assessing the spatial relationships of the important source and user activities identified in Section I. Spatial relationships are important in any reuse network because piping and pumping are usually expensive components of the system.

Step 1

Obtain a large (typical scale: 1 in = 500 ft) base map that shows all buildings, roads, grounds, etc.

Step 2

Circle in red all important potential source, user, and internal recycling activities identified in Section 1, and, most important, locate all treatment facilities, irrigated areas, and large industrial activities.

Step 3

Look for isolated, small flow volume activities in locations remote from the main area of activity. It may not be economically feasible to build a separate pipeline to carry a small volume of reclaimed water over long distances.

Table A-5 will aid in determining whether it is economically feasible to provide a pipeline for carrying a given reclaimed water flow over a given distance.

TABLE A-5. PIPELINE COSTS FOR ACTIVITIES USING RECLAIMED WATER

Activity Flow (gpd)	Hours of Operation (hrs/day)	Maximum Pipeline Distance Economically Affordable (ft)	
10,000	8 (24)	1,780	(3,650)
25,000	8 (24)	3,250	(6,080)
50,000	8 (24)	4,330	(9,120)
100,000	8 (24)	6,500	(24,600)
500,000	8 (24)	13,000	(30,420)

Eliminate from consideration isolated, small-volume activities that are clearly not good candidates for inclusion in a

reuse system on the basis of pipeline costs. Do not eliminate activities which are candidates for internal recycling; long pipelines are not necessary for internal recycling systems.

Step 4

Note areas of major potential reuse activity and areas that will be difficult to reach with reclaimed water lines, e.g., those cut off from the main base by runways or highways. Start to get a feel for the type of reuse that will be most feasible. Is the post essentially troop-oriented, with reuse of secondary effluent for irrigation the main possibility, or is it a heavily industrialized depot with possible reclaimed water cascades from one activity to another?

SECTION 3 - CONCEPTUAL REUSE SYSTEMS

This is the most important section of Tier II and requires the highest level of engineering judgement to complete. Its purpose is to assist the evaluator in selecting conceptual reuse schemes for an Army post.

Here, all the data gathered on activities and spatial relationships are used to develop feasible reuse networks or systems. These networks are essentially schematic diagrams showing the distribution of fresh and reclaimed water throughout the base, as well as the collection, treatment, reuse, and disposal of wastewaters. (Typical networks are shown on the following pages.) The first, Figure A-1, depicts a common reuse situation where STP effluent is used on the golf course. The second, Figure A-2, shows a more complex reuse scheme, including multiple STP effluent uses, plating wastewater reuse, and internal reuse at the tank wash rack.

Basic Types of Reuse

Several basic types of water reuse are practicable for Army posts, depending on the presence of treatment facilities, major industrial or irrigation activities, and other factors. Conceptual diagrams are presented in Figure A-3.

The various types of reuse are as follows:

- Treated effluent reuse: The direct reuse of secondary or tertiary effluent from an STP or IWTP by an activity, e.g., irrigation and cooling towers. Figure A-4 presents a list of other activities that can use effluent.

- Direct cascade reuse: The direct reuse, without treatment, of the discharge from one activity as the water supply for another activity. The donor activity usually has a fairly clean discharge and the user activity can tolerate low quality water. Feasible pairings are shown in Figure A-5.

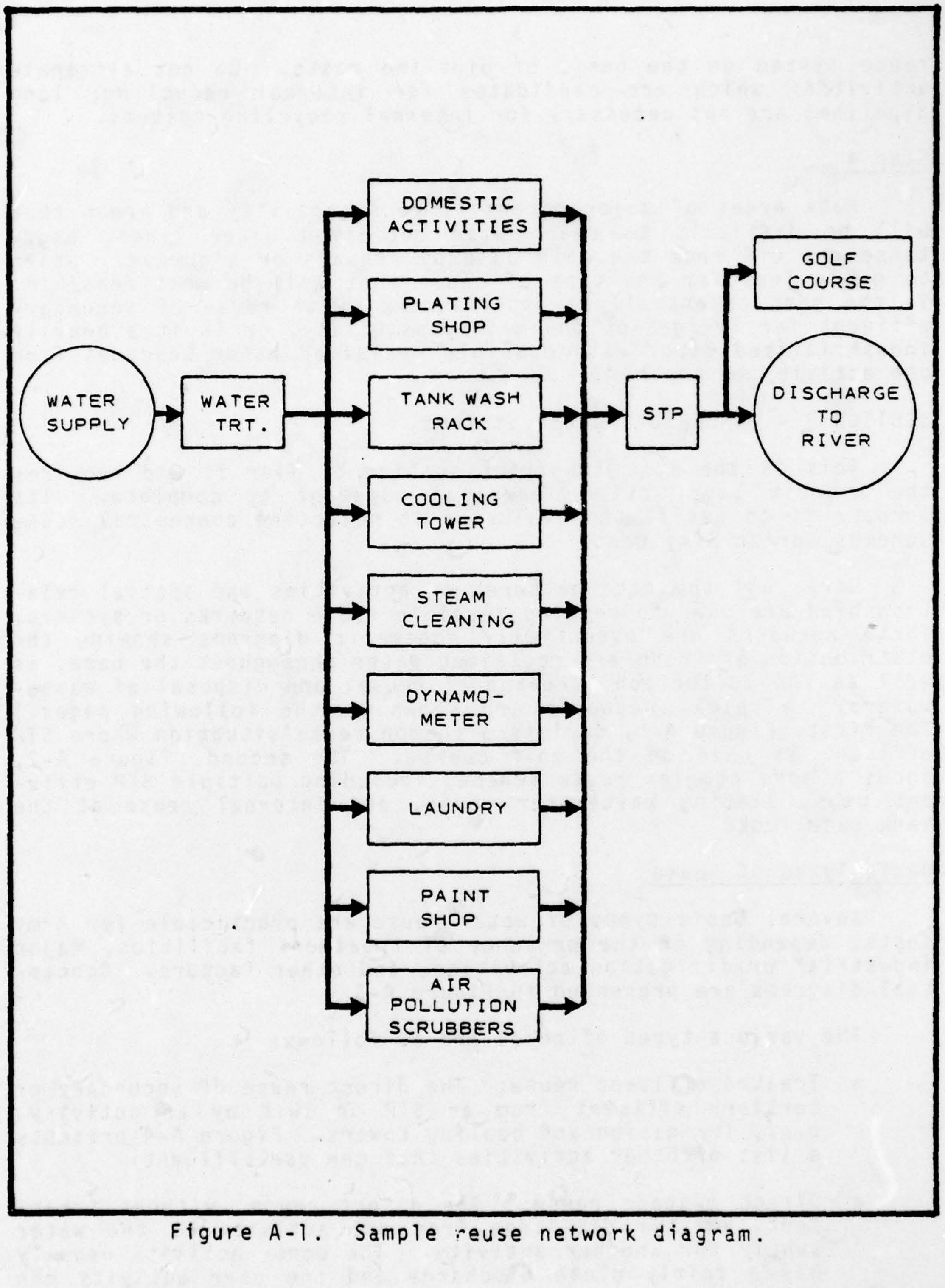


Figure A-1. Sample reuse network diagram.

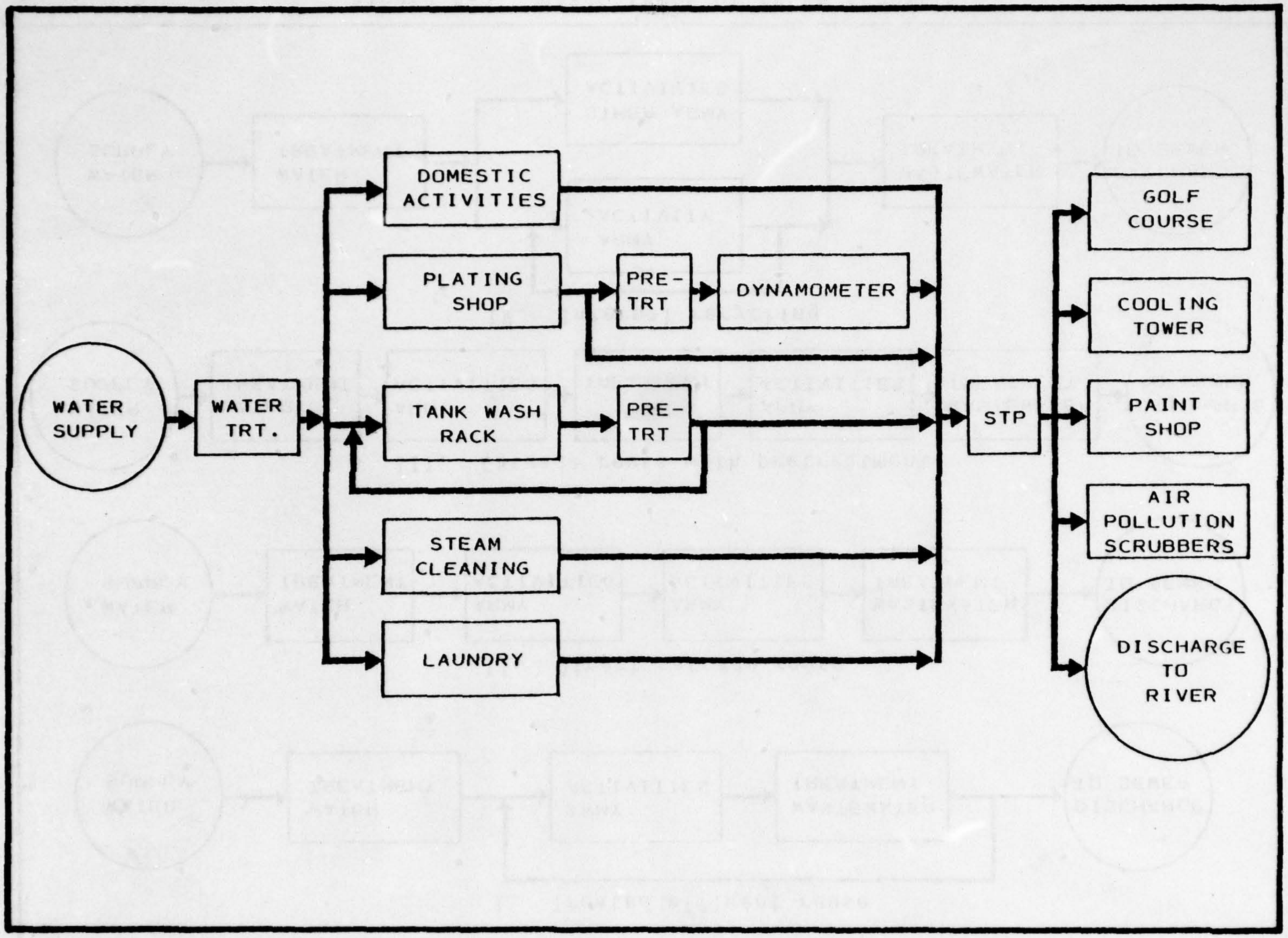


Figure A-2. Sample reuse network diagram.

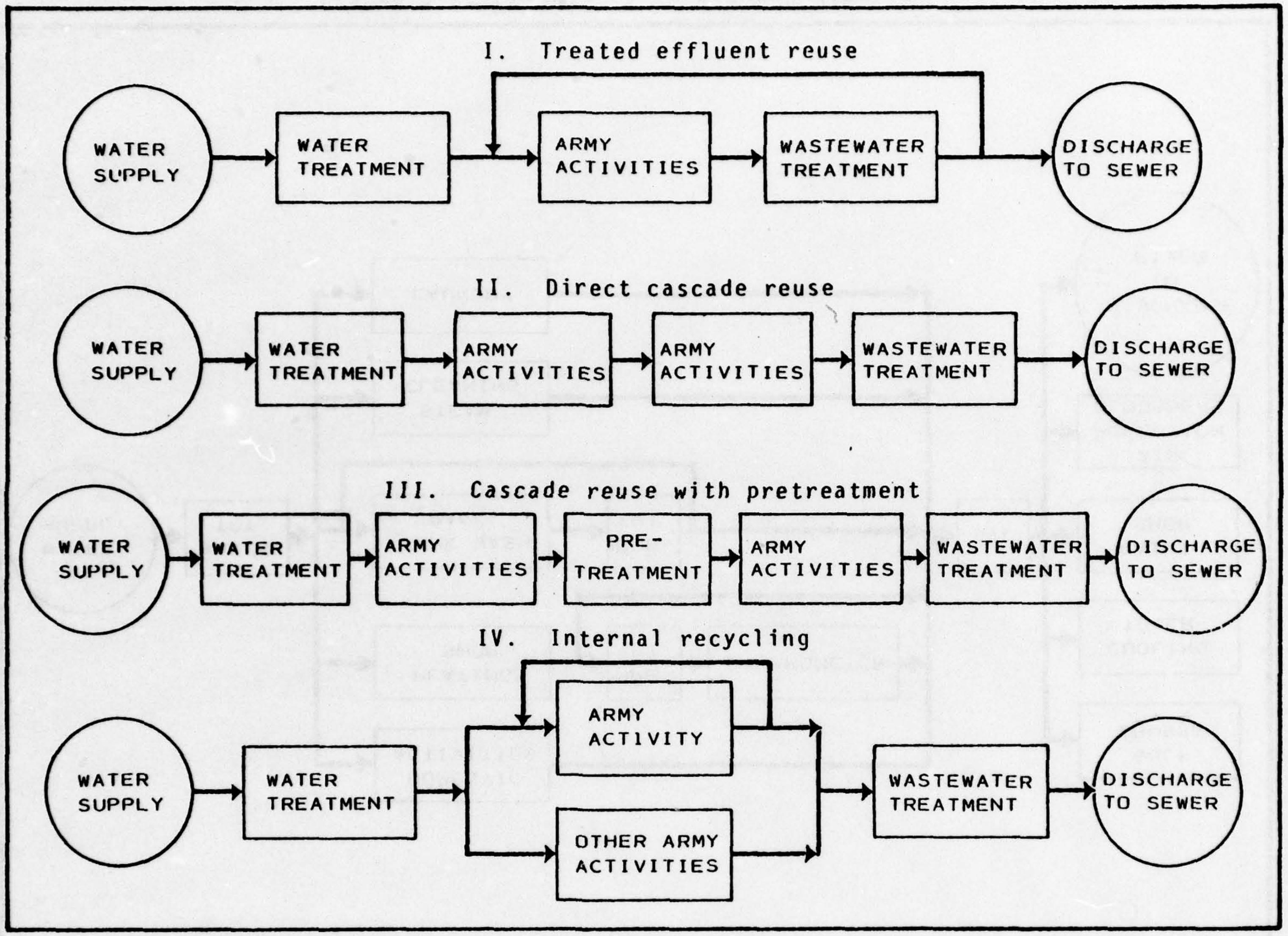


Figure A-3. Basic types of reuse schemes.

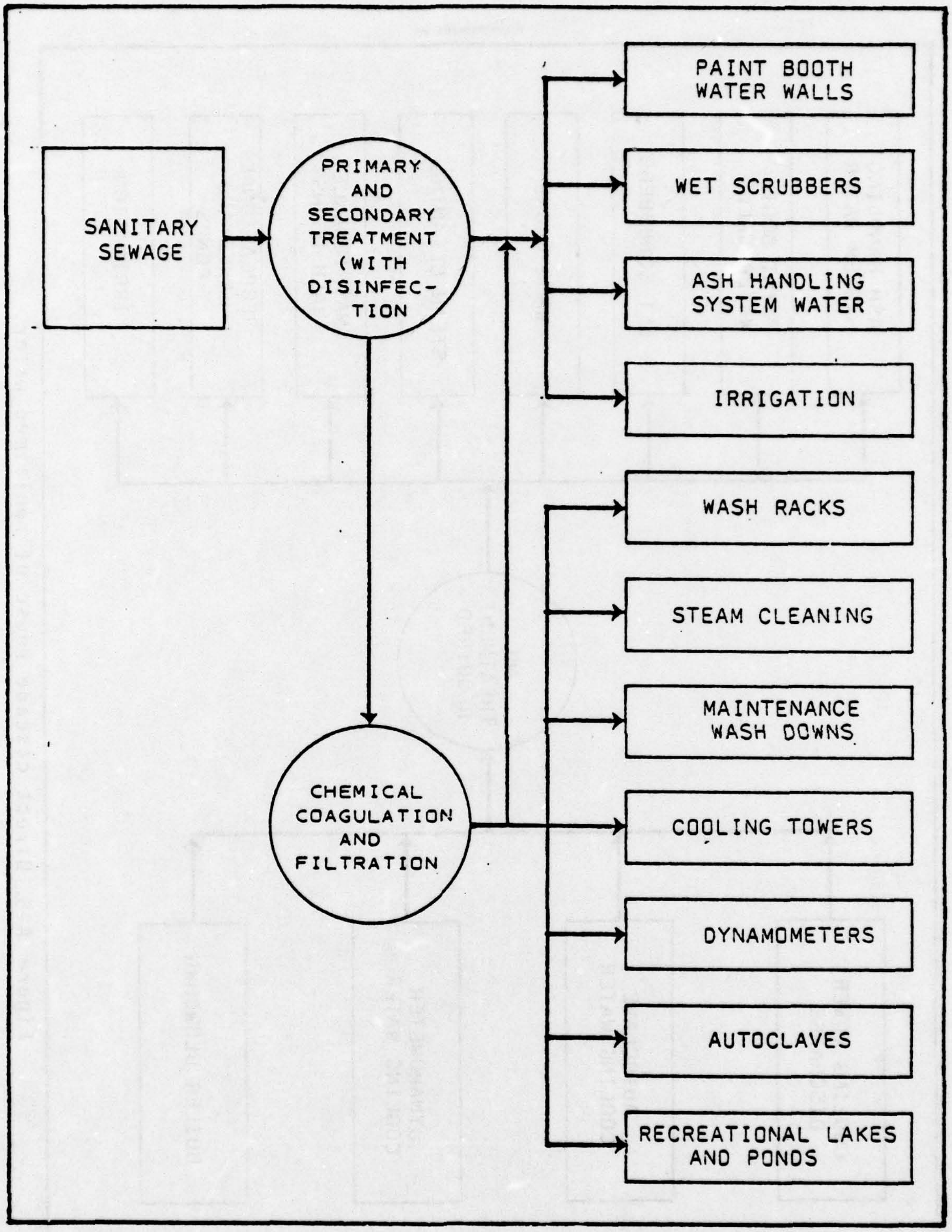


Figure A-4. Reuse of reclaimed sewage treatment plant effluent.

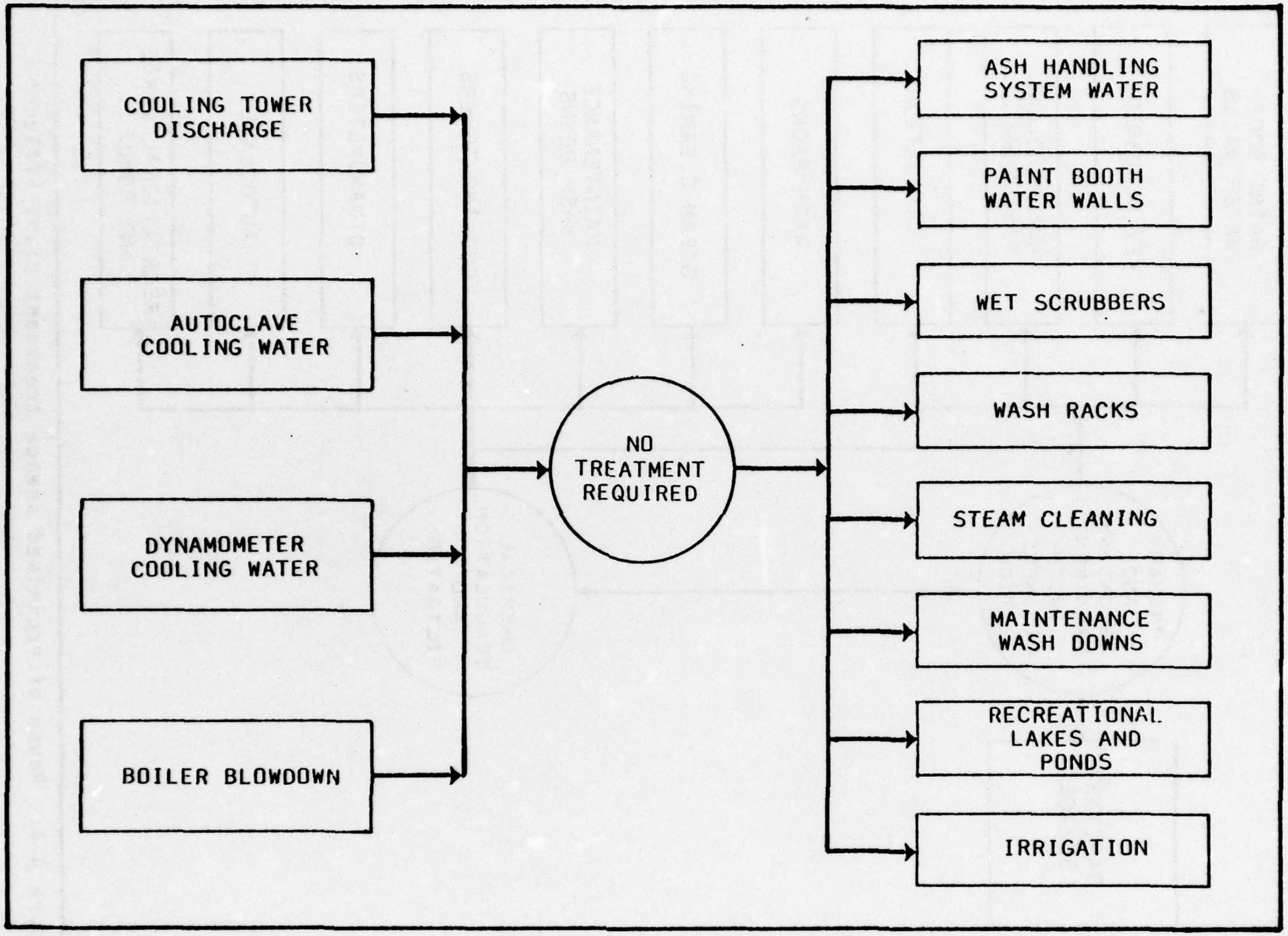


Figure A-5. Direct cascade reuse of reclaimed water.

- Cascade reuse with pretreatment: The same as direct cascade reuse with an intervening treatment step to bring the donor's wastewater up to the recipient's quality requirements. These pairings are generally feasible only where a simple treatment can do the job (Figure A-6).

- Internal recycling: The reuse of wastewater as new source water for the same activity. For instance, recirculating water is used to wash paint shop water walls and in air pollution scrubbers. The water can be continually bled off and made up, or periodically dumped and refilled. Other activities can be altered to internal recycling systems by treating the wastewater and mixing it in with a freshwater supply. Candidate activities are shown in Figure A-7.

Some posts may be able to incorporate more than one of the basic conceptual reuse systems in a total reuse scheme.

Step 1

At this point, the evaluator must compare actual post activities and existing treatment facilities, plan possible reuse modes, and develop feasible reuse schemes.

The most efficient way to lay out these networks is to first look at large sources and users, and then to develop a basic system. Smaller users, such as isolated cooling towers and small industrial operations, can be integrated where it appears cost-effective.

Step 2

The treatment processes required for each of the selected reuse systems can be selected by referring to Figures A-4 through A-7. Secondary treatment is conventional primary and secondary treatment (and disinfection) in a sewage treatment plant; tertiary treatment is chemical coagulation and filtration in addition to primary and secondary treatment.

Step 4

At this point, a general water balance for each network should be developed to aid in calculating required storage capacities and in ensuring that water supply requirements are met.

A water balance form (Table A-6) must be filled out; a sample completed form is shown in Table A-7. It is important to obtain data for maximum and minimum days or months. Such variations may be due to seasonal effects (e.g., irrigation) or changes in staffing levels (training, maneuvers, etc.). Storage requirements will depend on the differences between source and user activities during both minimum and maximum flow. This

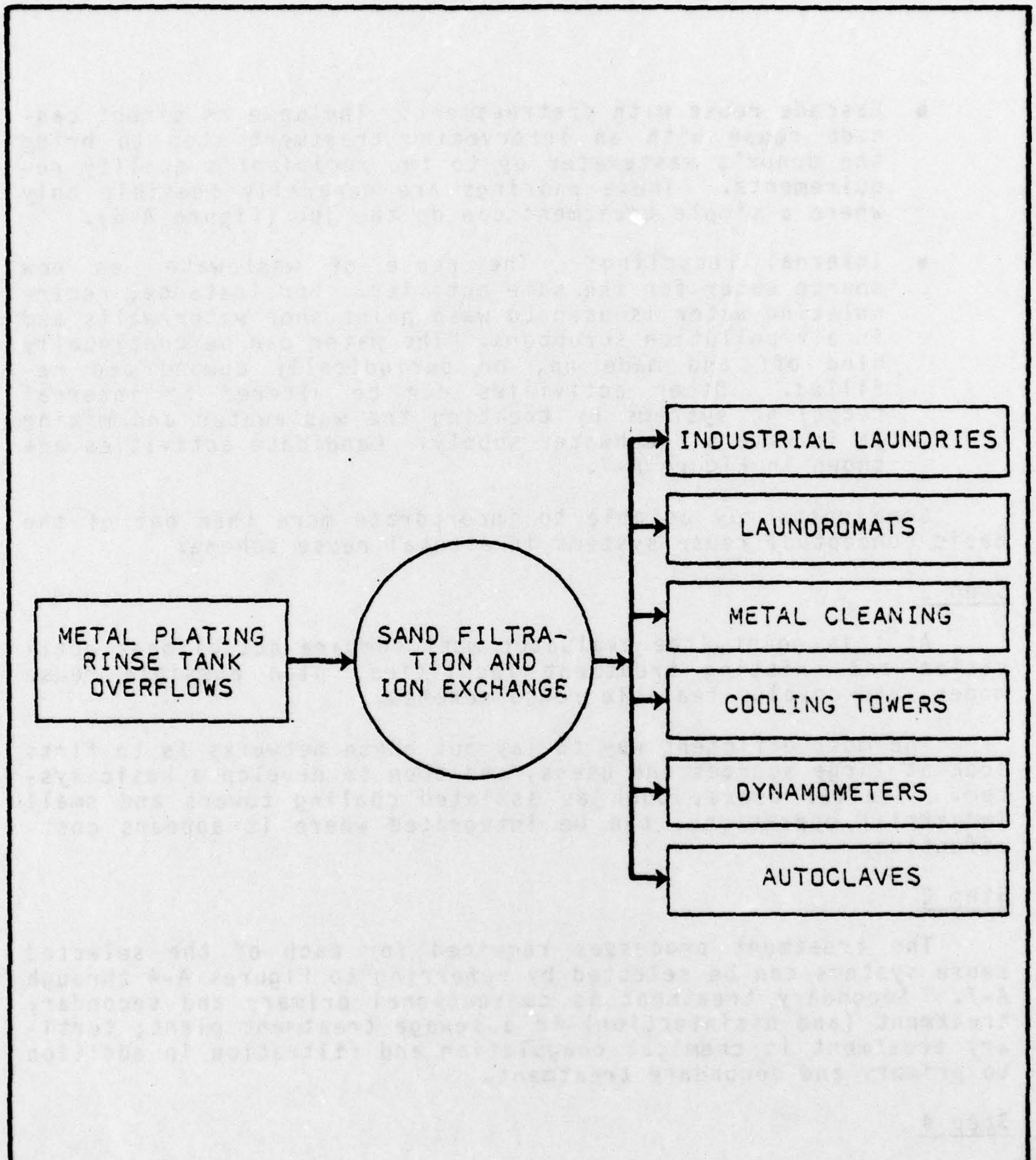


Figure A-6. Cascade reuse with pretreatment.

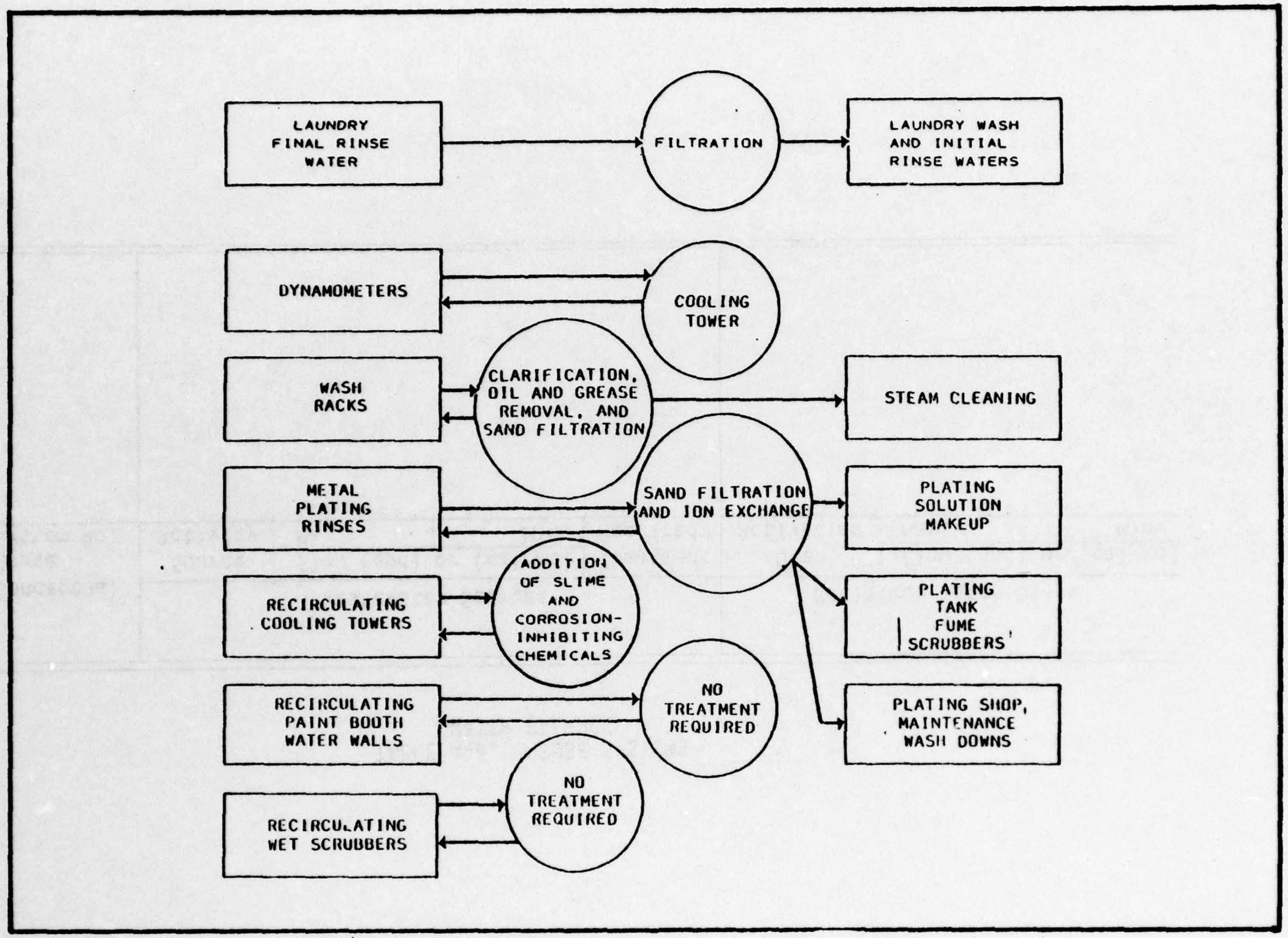


Figure A-7. Internal treatment and recycling.

TABLE A-6. REUSE SYSTEMS WATER BALANCE

Conceptual Reuse System No.	Wastewater Sources			Treatment Required	Reclaimed Water Users		
	Source Activity	Flow (gpd) or (gal/mo)			User Activities	Flow (gpd) or (gal/mo)	
		Max.	Min.			Max.	Min.

TABLE A-7. REUSE SYSTEM SAMPLE WATER BALANCE

Conceptual Reuse System No.	Wastewater Sources: Source Activity	Wastewater Sources: Flow (gpd) or (gal/mo) Max.	Wastewater Sources: Flow (gpd) or (gal/mo) Min.	Treatment Required	Reclaimed Water Users: User Activities	Reclaimed Water Users: Flow (gpd) or (gal/mo) Max.	Reclaimed Water Users: Flow (gpd) or (gal/mo) Min.
1.	Sewage treatment plant effluent	1,000,000	750,000	Secondary treatment plus sand filtration	Cooling towers	200,000	150,000
					Wash racks	30,000	10,000
					Steam cleaning	10,000	5,000
					Dynamometers	30,000	20,000
					Golf course and other area irrigation	2,000,000	0
2.	*Metal plating rinses*	*50,000*	*50,000*	*Sand filtration plus ion exchange**	Metal plating rinses	52,000	52,000
					Plating shop fume scrubbers	5,000	5,000
					Plating solution makeup water	1,000	1,000

*Already existing

tabular summary can then be transferred to the reuse network diagrams as demonstrated in Figure A-8.

The examples show daily generation, use, and storage. To calculate storage requirements for a full-scale system, the daily storage volume must be multiplied by the number of days at that condition. For example, in the first network in Figure A-8, the condition of no irrigation and low water use in other activities lasts 3 months. The required storage would be 270,000 gpd x 90 days = 24,300,000 gallons total for a zero discharge system. Another option would be to discharge a portion of the effluent, and to reduce storage costs if this were economical.

Where seasonal variations are large, it is often valuable to develop water balances on a monthly rather than daily basis. The concept is the same with total maximum and minimum monthly flow data being used instead of daily data.

SECTION 4 - REUSE ECONOMICS

This section is the key to the Tier II evaluation model. The overall cost of alternative reuse schemes for a particular post can be estimated using the information gathered in Sections 1 through 3.

These reuse system costs will also be compared to: 1) the costs of the zero reuse situation (usually the existing condition); and 2) the costs of anticipated near-future situations, such as new water supply costs, new treatment facilities, and regional sewer system hook-up. In this way the economic validity of reuse can be estimated, and a decision can be made as to whether to proceed to Tier III.

The important capital, operation, and maintenance costs that will be computed are:

- Existing water supply cost
- Existing wastewater treatment and/or disposal cost
- Cost for new reclaimed water pipelines
- Cost for reclaimed water storage
- Cost for reclaimed water pumping
- Cost for new treatment facilities for reclaimed water.

Step 1

Costs for the existing system, which will usually have no reuse, must be calculated, including operation and maintenance costs for the water supply, and wastewater treatment and discharge.

In addition to existing costs, it is well to include anticipated future costs if major changes are planned, e.g.,

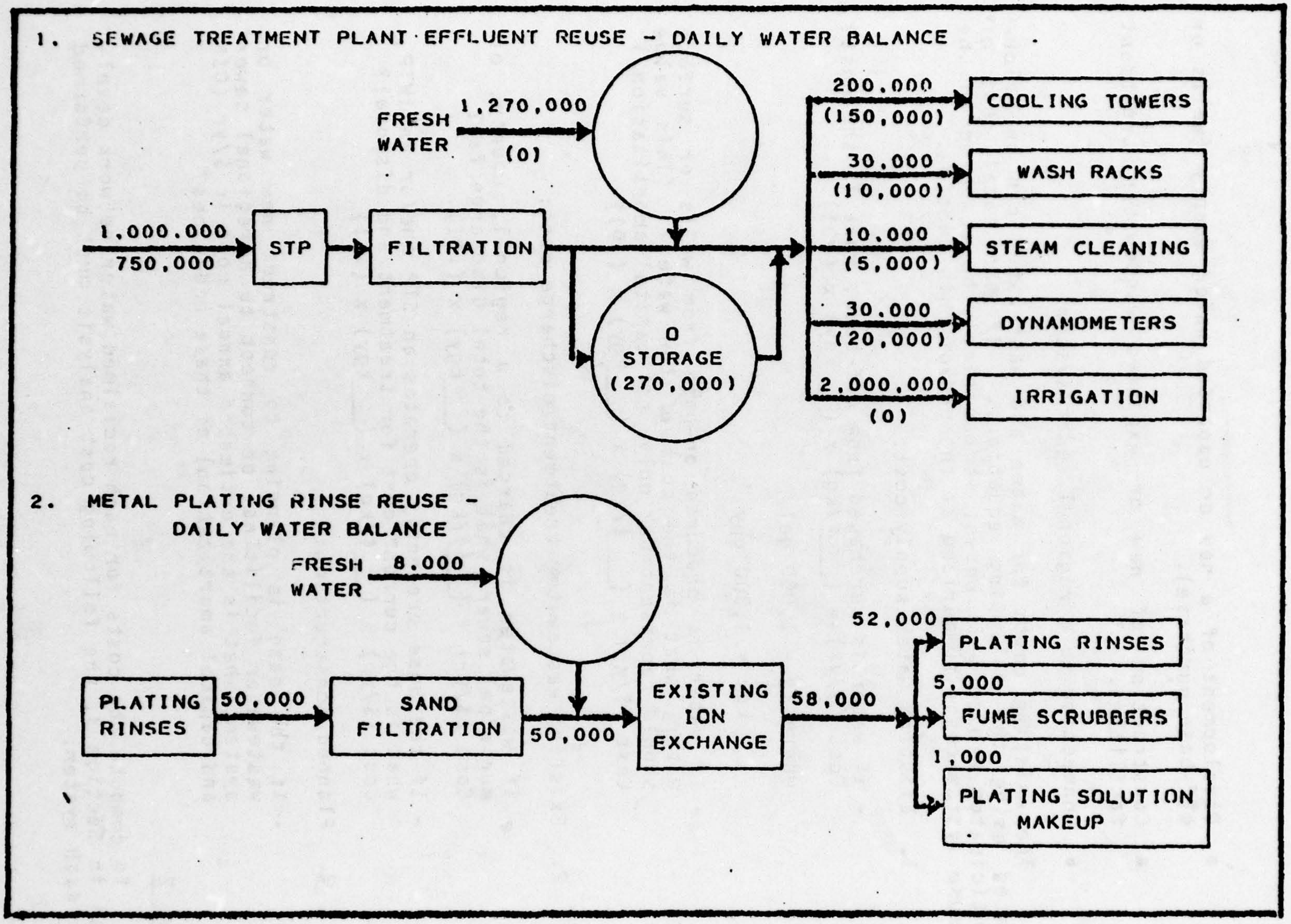


Figure A-8. Sample water balance diagrams for conceptual reuse systems showing flow rates (GPD, max. and min.) requirements for storage and additional fresh water.

- Development of a new or expanded water supply (wells or off-base purchase).
- Construction of new or expanded wastewater treatment facilities.
- Connection to a regional sewer system.

The existing costs for water and wastewater can be calculated using the following equations. If the total cost of anticipated projects is known, it can simply be compared to the reuse system costs summarized at the end of this section.

1. Existing water supply cost:

   - If water is purchased from off-base, what is the cost?
     Cost ($/yr) = (___¢/kg) x (___kgy) x (.01)

     where kg = 1,000 gal

     kgy = 1,000 gpy

   - If water is procured on-base from wells or surface water, what is the cost of the water? (This value should represent O&M only, not capital amortization.)
     Cost ($/yr) = (___¢/kg) x (___kgy) x (.01)

2. Existing wastewater treatment/discharge cost:

   - If wastewater is charged to a regional, county, or municipal sewer, what is the total discharge fee?
     Cost ($/yr) = (___¢/kg) x (___kgy) x (.01)

   - If the base presently operates an STP and/or an IWTP, what is the current cost for treatment and disposal?
     Cost ($/yr) = (___¢/kg) x (___kgy) x (.01)

3. Planned construction:

   - If the base is planning to construct new water or wastewater facilities, or connect to a regional sewer system, what is the estimated annual cost in $/yr (O&M and capital amortization) of these additions?

Step 2

To compute the costs for each reclaimed water network developed in Section 3, the following cost analysis must be performed for each system:

1. Modified water supply cost--
Recalculate the annual water supply cost (developed above) due to any reduction in water demand via reuse.

2. Modified wastewater treatment/discharge cost--
Recalculate the annual wastewater treatment/discharge cost based on flow and fee reductions due to reuse. If the base provides treatment, calculate the new annual treatment cost based on flow reductions due to reuse.

3. Reclaimed water pipelines costs--
Using the base map for reference, mark off the distances of the new reclaimed waterlines for each conceptual reuse activity network. Do not include existing pipelines.

3a. Using the activity flow data as well as engineering judgment, estimate a pipe diameter for each new reclaimed waterline. The following equation can be used to calculate minimum diameter when given flow in gph and maximum velocity (ft/sec) in the pipe:

$$\text{Dia (in)} = (\text{gph} \times 144 \times 4/\text{velocity} \times \pi \times 7.48 \times 3{,}600)^{1/2}$$

Note: 5 ft/sec is a typical flow velocity

3b. Calculate the capital cost for each pipeline by substituting into the following formula:

$$\text{Capital cost (\$)} = (2.0)\,(\text{Dia})\,(L)\,\frac{CCI}{2103}$$

where dia = diameter in inches

L = length in feet

3c. Note that these costs reflect conventional trenching and pipe placement. These costs will have to be increased appropriately for trenching under heavy pavement. These costs, however, do include contingencies and some internal plumbing and connections. Add all individual pipe costs together for the entire reuse network.

4. Reclaimed water storage costs--

4a. From the resue network water balance, calculate the maximum storage volume required for each location in the system. Then, apply a safety factor to provide additional storage according to the following equation:

$$AS = 50.0 \times (MSV)^{0.7}$$

where AS = additional storage in gal

(MVS) = maximum storage volume in gal

4b. Add this safety storage to the actual volume required to get the total design volume.

4c. Calculate capital cost for storage:

$$\text{Capital cost (\$)} = 22.95\ (\text{vol})^{0.6}\ \frac{CCI}{2870}$$

where vol = total design volume in gal

4d. Add the annual costs for each storage tank to get the total annual storage cost.

5. Reclaimed water pumping costs--
For simplification, assume that one pump station will be used to pressurize the entire reclaimed water network whether it is simple or complex. Calculate the maximum total hourly flow through the system and substitute that value in the equations below:

$$\text{Capital Cost (\$)} = (204.43)(Q^{0.48})\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (5.23)(Q^{0.766})\ \frac{LCI}{4.71}$$

where Q = flow (gph)

6. Reclaimed water treatment costs--
Treatment for the reclaimed water system can take two forms: 1) entirely new treatment facilities may be constructed for the reuse programs; or 2) existing plants may be modified or expanded to improve performance. Many bases already have trickling filter STPs which can be upgraded with the use of chemical coagulation and filtration units. Refer to Section 3 for previously determined treatment requirements, select required treatment units, and utilize the following cost equations where appropriate.

6a. <u>Conventional secondary treatment</u>--Conventional secondary treatment consists of primary clarification, trickling filter secondary treatment, final clarification, chlorination, anaerobic digestion, and sludge drying beds. Costs are complete and include all site work, structure, mechanical apparatus, electrical work, and installation.

$$\text{Capital Cost (\$)} = (826.0)(Q^{0.485})\ \frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (151.0)(Q^{0.388})\ \frac{LCI}{4.71}$$

where Q = flow (gpd)

6b. <u>Filtration</u>--Capital and annual O&M costs for multimedia filtration (at a loading of 4 gpm/sq ft) represented by the following equations:

$$\text{Capital Cost (\$)} = (29.97)(Q^{0.631})\frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (5.95)(Q^{0.633})\frac{LCI}{4.71}$$

where Q = flow (gpd)

6c. Oil and grease removal--The oil and grease removal unit is assumed to be an API-type separator. Costs include concrete, mechanical scrapers and rakes, electrical, and installation.

Capital and O&M costs for oil and grease removal are represented by the following equations:

$$\text{Capital Cost (\$)} = (36.28)(Q^{0.713})\frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (0.31)(Q^{0.824})\frac{LCI}{4.71}$$

where Q = flow (gpd)

6d. Ion exchange--Capital and O&M costs for ion exchange are represented by the following equations:

$$\text{Capital Cost (\$)} = (5{,}000 + 0.02Q)\frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (0.36Q)\frac{LCI}{4.71}$$

where Q = flow (gpd)

6e. Slow sand filtration--Costs for slow sand and filter beds include all earth work, drainage tile, media preparation, and associated mechanical and electrical work.

Costs for slow sand filtration are represented by the following equations:

$$\text{Capital Cost (\$)} = (0.15Q)\frac{CCI}{2103}$$

$$\text{Annual O\&M Cost (\$/yr)} = (0.0043Q)\frac{LCI}{4.71}$$

where Q = flow (gpd)

6f. Clarification (pretreatment)--Clarification consists of a circular sedimentation basin and a gravity solids thickener for application as an activity wastewater pretreatment process. Capital costs include structure, equipment, pumps, and integral piping and appurtenances. Operation and maintenance costs include labor, power, fuel, and other materials.

Capital and O&M costs for clarification are represented by the following equations:

$$\text{Capital Cost (\$)} = (0.109)(Q^{1.01})\frac{CCI}{2870}$$

Annual O&M Cost ($/yr) = $(29.88)(Q^{0.428}) \frac{LCI}{5.25}$

where Q = flow (gpd)

7. After calculating these costs for the current situation and each reuse network, a final economic comparison can be made.

Step 3

Table A-8 can be used in summarizing and tabulating costs for existing water use as well as selected reuse schemes.

By comparing the total annual costs, of each system, the most workable can be selected, and the economic feasibility of reuse versus the existing or planned system can be assessed. For example, a future option may be connection to a regional sewer system for a specified annual cost. The cost summary in Table 8 will tell you whether reuse is an economically competitive alternative. For example, assume a base has been asked to hook-up to a new regional sewer/treatment system. The initial capital cost for the connection and for purchase of treatment plant capacity is $5 million with an additional $250,000 per year in O&M costs. Results of the Tier II evaluation show that the best reuse system that will reuse nearly 100 percent of the base's wastewater will cost only $2.8 million in capital dollars and $150,000 per year in O&M costs. This would indicate that a Tier III evaluation is warranted.

Much of the data obtained in Tier II can be expanded for use in Tier III. Activity data, preliminary reuse network layouts, and basic cost information can all be used as a basis for gathering the reuse detailed data for Tier III.

TABLE A-8. SUMMARY COST COMPARISON FOR REUSE SYSTEMS

Date: ____________

Post: ____________

Evaluation: ____________

Reuse Network Number	COSTS														
	Water Supply ($/yr)	WW Discharge Fee ($/yr)	Existing WW Treatment Plant ($/yr)	News Trt. for Reclaimed Waste		Piping		Pumping		Storage		Total O&M ($/yr)	Total Capital ($)	Total Annual Capital ($/yr) (1)	Total Annual ($/yr)
				Capital ($)	O&M ($/yr)	Capital ($)	O&M ($/yr)	Capital ($)	O&M ($/yr)	Capital ($)	O&M ($/yr)				
1															
2															
3															
4															

(1) Total annual capital cost = (0.10185) x total capital cost ($); this assumes a 20-year operational life, 8 percent interest, and zero salvage value.

ARMY
WASTEWATER REUSE POTENTIAL
EVALUATION MODEL

TIER III

Tier III of the Army Wastewater Reuse Potential Evaluation Model is a modification of a computer model previously developed by SCS Engineers for the Air Force.

This tier is comprised of two basic parts, as discussed previously in Section IV. The first involves collection of activity data for input to the model. The second involves review of the Phase I computer program output, and the creation of feasible reuse networks for the post.

All required data and recording forms are provided in the "User Manual," Volume II of this report. This document will be shipped to the Environmental Division of the U.S. Army Corps of Engineers, Construction Research Laboratory (CERL), Champaign, Illinois. They have the computer facilities to run the program, store data, etc. The following will be provided to CERL:

- "Cascade Water Reuse," CEEDO-TR-77-19, by SCS Engineers for Civil and Environmental Engineering Office (Air Force Systems Command), Tyndall AFB, July 1977

- A copy of the Subpotable Reuse Program (daily and yearly simulation programs)

- Users Manual for the daily program, with addenda sheets for the modifications for the yearly simulation program.

Note that Tier III follows immediately from Tier II. The same type of data is required, only in more detail. The Tier II data on activities, costs, and preliminary reuse network layouts should be used as the data base from which Tier III expands.

ACRONYMS

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
STP	Sewage Treatment Plant
IWTP	Industrial Waste Treatment Plant
O & G	Oil and Grease
SS	Suspended Solids
DS	Dissolved Solids
MPN	Most Probable Number of Coliform Bacteria
gpd	gallons per day
gpcd	gallons per capita per day
mg/L	milligrams per Liter

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